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The Use of Compost from Post-Consumer Wood Waste Containing Microbiological Inoculums on Growth and Flowering of Chrysanthemum (*Chrysanthemum × grandiflorum* Ramat./Kitam.)

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Abstract: The purpose of the conducted study was to assess the possibility of using composts made from post-consumer wood containing waste of fibre boards and microbiological inoculums in chrysanthemum (*Chrysanthemum × grandiflorum* Ramat./Kitam.) 'Jewel Time' cultivation. Five variants of composts (marked ask, KK, AL, AL + K, EM, EM + K) were prepared, each variant was duplicate. All variants consisted of fibreboard waste (60% of its weight), mixed with mature compost made from fibreboard waste (30%), Protohumovit-biologically active organic fertilizer with the chemical composition of cattle manure (3%), starch, sugar, corn oil (together 7%). A biological inoculum "Activit Las" was added to one half of reactors. "Activit Las" (produced by Atlas Planta S.C, Bydgoszcz) is biological inoculum containing of selected bacteria, actinobacteria and fungi, that is intended to accelerate the composting of lignocellulosic materials, including wood from forest and sawmill. The second part of reactors was implemented by microbiological inoculum (EM) from Greenland Technologia EM (Trzcianki, Poland). A Bio Best (produced by Atlas Planta S.C, Bydgoszcz) formulation of chicken manure was added to some of the reactors containing EM and Activit Las. Compost without any additional microorganisms and microelements was control for experiment. Plant quality depended on the dose of compost used as well as on the type of microbial inoculations used during the composting process. The addition of composts containing the EM microbial inoculation to peat stimulated the formation of inflorescences and inflorescence buds. It also had a positive effect on the size and number of leaves. An additional effect of using compost obtained from wood waste is the reduction in the consumption of natural resources such as peat.

Keywords: biological utilisation; composting of wood waste; microbiological inoculums; chrysanthemum

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1. Introduction

Peat is one of the most widely used and at the same time the best natural substrates for horticulture production; for growing vegetables, fruit, ornamental plants, mushrooms and nurseries and forestry [1]. It offers unique physical and chemical properties and is safe in phytosanitary terms, but it is a non-renewable resource. Moreover, the exploitation of peatlands increases CO_2 emissions and negatively affects the environment [2,3]. Considering the natural importance of peatlands, the European Union has introduced radical restrictions related to the exploitation of peatlands and the extraction of peat for the production of horticultural substrates [4].

In the recent years, many alternative materials have been evaluated to protect this ecologically important resource. Despite the valuable properties of peat to grow plants, the drainage and excavation of peatlands release greenhouse gas into the atmosphere [3,5].

Thus, renewable materials such as wood fibre, bark, coir, biochar, compost and inorganic materials are becoming key components of the horticultural industry [1].

The use of various types of wood waste as a source of organic matter that can be added as compost to horticultural substrates is rarely discussed in papers. The use of wood waste as a raw material for compost production in practice only applies to wood waste obtained from forests, from the maintenance of green areas and to wood from technological processes that do not use chemicals.

Composting using appropriate, effective micro-organisms offers an opportunity to manage wood waste that is difficult to manage in traditional technological processes. Such waste includes dry processed fibreboard waste (e.g., from MDFs). All types of waste containing fragments of these boards are suitable for biological utilisation. The production of MDF, HDF and LDF dry processed fibreboards is growing rapidly, and their lifespan has been estimated at 14–20 years. Thus, a significant amount of production and post-consumer fibre waste will need to be managed using biological methods [6].

Wood, as well as wood-based materials and wood waste, contain nearly 90% organic matter, the main components of which are carbohydrates (65–75%) and lignin (18–35%) [7–10]. This matter should be recovered through the aerobic process of biological decomposition and incorporated into the biocycle by obtaining humus preparations (composts) and regenerating depleted, eroded and contaminated soils with organic matter (humus) [11]. The regeneration of eroded soils with composts or organic fertilisers produced from wood waste may contribute to reducing soil erosion and increasing soil organic matter content, which is also in line with the concept of Circular Economy in the aspect of soil as a natural resource, as well as the new EU strategy for soil protection [12].

The composting of organic waste is the most common technology of recycling and disposing of them easily in a safe way [13]. Composting should be understood as recovery of waste and more precisely as organic recycling. The definition of organic recycling states that it is oxygen (aerobic) treatment, including composting, or oxygen-free processing of waste which is biologically degraded in the controlled conditions by bacteria, as a result of which organic matter or methane is produced; disposal on a waste landfill is not regarded as organic recycling. Research into the influence of composts made from (among others) timber industry waste (bark, wood chips, sawdust), sewage sludge or urban waste and industrial waste on the plant growth has been conducted by numerous researchers [14–16].

So far, it has been reported that composts made from both production and municipal wood waste can serve as a substrate for ornamental plant growing media. The research conducted so far has shown that the production wood waste is suitable for biological utilisation by composting, and the composts obtained from it are characterised by a high content of organic matter. The obtained composts did not exceed the permissible content of heavy metals. The content of macro- and microelements and contaminants in the obtained composts depended on the type of waste from which the compost was made.

Composts made from wood-based material waste obtained in a sufficiently long composting process had physical properties (colour, smell, bulk density) similar to those of horticultural substrates produced using peat and may be used as its substitute, which is connected to peatland protection and is in line with the concept of resource-efficient economy [17–21].

Lignocellulosic wastes such as wood, green waste, agricultural, forestry wastes and municipal solid wastes should be converted or used as potentially valuable material to avoid landfilling. One of the possibilities to utilise wood waste is to use it in composting process [22,23].

There are so many factors affecting the composting process such as raw materials, times, environmental conditions and so on. The inoculation does not always show a good performance due to the competition between inoculant and indigenous microbes, the timing of inoculation and the type of inoculation. The microbial inoculum can be composed of a single culture, mixed culture and mature compost. The use of microbial additives during composting is considered highly efficient, likely to enhance the production of different enzymes resulting in better rate of waste [24].

The use of microbial inoculations in the processes of decomposition of organic matter of natural origin, including animal manure or sewage sludge, is discussed in the literature [25].

Effective microbe or microorganisms (EM) is a type of microbial inoculant developed and introduced by Teruo Higa from Japan [26]. Effective microorganisms consist of a combination of several microorganism species that belong to the following groups: lactic acid bacteria, photosynthetic bacteria, actinobacteria, yeast fungi and filamentous fungi [27]. For example, *Lactobacillus plantarum* may accelerate the decomposition and fermentation in composting process. *Streptomyces albus* produce antibacterial matter for pathogenic bacteria and *Rhodobacter sphaeroides* involve in production of amino acids and amino nucleic. *Saccharomyces cerevisiae* and *Candida utilis* promote fermentation and produces bioactive substances [23]. The application of EM in compost production was proven to accelerate composting process [28,29]. Few studies successfully assessed the impact of EM inoculation on the humification of lignocellulosic and cellulosic waste and none assessed any negative effects on compost. In this context, bio-degradation of organic matter and lignocellulosic waste with optimised inoculation strategy, resulted in enhanced mineralisation of organic carbon and accelerated lignocellulose degradation, achieving good humification in waste [30]. The search for organism and inoculation dedicated to specific groups of wastes may influence the increase of their use as components of composts. In turn, obtaining good quality composts may result in a wider use in horticultural production, especially in the production of ornamental plants.

Chrysanthemum is a one of the most important species cultivated worldwide. In Europe, it is a very popular potted plant of great economic value. Substrates based on high peat are mainly used in the cultivation process of this species.

The purpose of the following study was to assess the possibility of using compost made from post-consumer wood waste containing microbiological inoculums on growth and flowering of chrysanthemum (*Chrysanthemum* × *grandiflorum* Ramat./Kitam.) 'Jewel Time'. The conducted experiment focused on assessing the quality of the cultivated plants.

2. Materials and Methods

2.1. Composts Preparation

The aim of the study was the possibility of application of compost from post-consumer wood-containing waste of fibreboard and microbiological inoculums as a substitute of peat in plant cultivation.

Composts from post-consumer wood were prepared in the Łukasiewicz Research Network-Poznan Technology Institute, Wood Technology Centre. Post-consumer wood came from the bulky waste landfill site of Waste Management Company in Poznań and comprised old furniture. The waste consisted of the hard fibre boards (raw and varnished). Selected waste was preliminarily crushed in a Hammel crusher. Wood material that was subject to composting was ground to particle size less than 10 mm. Investigations were carried out in 10 chambers of the bioreactor of 160 dm^3 each.

Five variants of composts (marked ask: KK, AL, AL + K, EM, EM + K) were prepared, each variant was duplicate. All variants consisted of fibreboard waste (60% of its weight), mixed with mature compost made from fibreboard waste (30%), Protohumovit-biologically active organic fertilizer with the chemical composition of cattle manure (3%), starch, sugar, corn oil (together 7%) was used. A biological inoculum "Activit Las" was added to one half of reactors. "Activit Las" (produced by Atlas Planta S.C, Bydgoszcz) is a two-component preparation-component A—a mineral carrier containing bacteria and actinomycetes, component B—an organic carrier on which fungi are deposited, mainly *Trichoderma* sp. and *Penicillium* sp. The preparation is intended to accelerate the composting of lignocellulosic materials, including wood from forest and sawmill. The second part of reactors was implemented by microbiological inoculum (EM) containing photosynthetic bacteria: *Rhodopseudomonas palustris*, *Rhodobacter spaeroides*; actinobacteria: *Streptomyces* *griseus*, *Streptomyces albus*; fermenting fungi: *Aspergillus oryzae*, *Mucor hiemalis*; lactic acid bacteria: *Lactobacillus* sp., *Streptococus lactis*; yeast: *Saccharomyces cerevisae*, *Candida utilis* from Greenland Technologia EM (Trzcianki, Poland). A Bio Best (produced by Atlas Planta S.C, Bydgoszcz) formulation of chicken manure was added to some of the reactors containing EM and Activit Las (Table 1). All reactors were placed outdoor in the shadow place. Temperature in the reactors and ambient temperature was measured (Figure 1).

Table 1. The combinations of compost mass in reactors.

Reactors Number	Name	Post-Consumer Wood Waste	Fibreboard Mature Compost	Protohumowit	Starch, Sugar, Corn Oil, Water	Activit Las 1200 mL	EM 250 mL	Bio Best
1	KK	√	√	√	√			
2	KK	√	√	√	√			
3	AL	√	√	√	√	√		
4	AL	√	√	√	√	√		
5	AL + K	√	√	√	√	√		√
6	AL + K	√	√	√	√	√		√
7	EM	√	√	√	√		√	
8	EM	√	√	√	√		√	
9	EM + K	√	√	√	√		√	√
10	EM + K	√	√	√	√		√	√

√: It means the content of various additives in the compost.

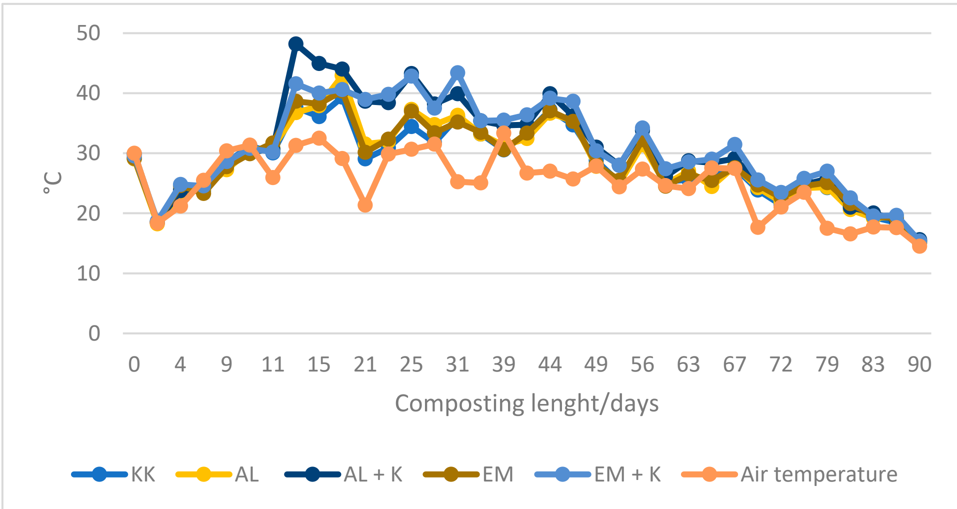

Figure 1. Temperature during the composting process.

The reactors were turned every week at the beginning of experiment and every second week at the end. Moisture content of composted mass was tested, to be sure that the value of the parameter was in the range between 55 and 75%. If the value was too low, water was added to the compost.

Each variant of compost was mixed and collected before sampling for potting tests. Selected physiochemical parameters and content of elements in composts before potting medium preparation were examined (Tables 2 and 3).

Table 2. Selected parameters of compost from reactors before mixed with peat.

Name	Dry Mass	Ash	Density
	%		$g \cdot dm^3$
KK	32.7	10.5	320
AL	32.2	11.5	330
AL + K	31.2	15.8	350
EM	32.8	11.4	382
EM + K	30.9	15.9	322
Control-Peat	31.3	15.6	330

Table 3. The chemical composition of the composts before mixing of potting growing medium.

Medium	$N\text{-}NO_{3-}$	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cl	Salinity g $NaCl \cdot dm^3$	pH
	$mg \cdot dm^{-3}$											
Control-peat	209	71	210	963	101	86.4	23.8	6.5	1.7	42	1.56	5.3
KK	130	57	250	1022	113	53.6	16.5	374.0	2.2	51	1.64	5.5
EM	165	39	250	1012	114	67.5	18.9	322.0	2.1	56	1.67	5.4
EM + K	162	107	370	1101	137	57.6	18.6	314.5	2.0	89	1.86	5.4
AL	162	64	240	943	111	56.8	17.6	371.0	1.9	55	1.53	5.4
AL + K	161	93	335	873	118	52.4	19.3	276.5	2.0	91	1.48	5.5

2.2. Experimental Design

Vegetation experiment was conducted in an unheated plastic tunnel located at the Experimental Station of the Departments of the Faculty of Agronomy, Horticulture and Bioengineering (Department of Ornamental Plants, Dendrology and Pomology). The plastic tunnel was equipped with darkening curtains made of a two-layer material of Obscura A/B + B type. Plants were darkened during the hours between 18:00 P.M. and 8:00 A.M. The studies were conducted in controlled cultivation on chrysanthemum (*Chrysanthemum* × *grandiflorum* Ramat./Kitam.) 'Jewel Time' as a model plant. Five rooted cuttings were planted into pots of 12 cm diameter (V 659 cm^3). Three days after potting, the plants were pinched off above the fifth leaf, counting from the base of the shoot. The chrysanthemums were retarded using the daminozide in the concentration of 2550 $mg \cdot dm^{-3}$ (contained in the B-Nine 85 SP preparation). The treatment was applied first when lateral shoots (after pinching) attained a length of 10–15 mm. Two further treatments were given every 7–10 days.

The plants were cultivated in substrates consisting of peat with addition of KK, AL, AL + K, EM, EM + K composts in different volume ratios (Table 4). Particular combinations of substrate were as presented in Table 1. Fertigation was carried out using a doser from Dosatronic Co. Ravensburg, Germany Superba Brown Yara (14.1% N, 9.2% P, 25.4% K+ microelements); fertilizer was used for fertigation in the concentration of 0.1%, starting from the second week after planting.

Table 4. The combinations of substrate.

Substrate Treatments	Compost KK, AL, AL + K, EM, EM + K	Peat
I	50%	50%
II	25%	75%
Control		100%

The experiment comprised 11 combinations (KK, AL, AL + K, EM, EM + K and Control), each of which consisted of 16 replications, where one replication was one pot with five plants. The control group consisted of plants grown in high peat substrate. Chemical composition of substrate used for experiment both before and also after plant cultivation is shown in Table 5.

Table 5. The chemical composition of the medium used at the beginning and after the end of the experiment.

Medium	$N\text{-}NO_3$-	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cl	Salinity g NaCl·dm^3	pH
	mg·dm^{-3}											
beginning of the experiment												
Control-peat	84	51	111	1707	228	24.14	1.53	17.73	1.65	106	1.50	6.5
end of the experiment												
Control-peat	891	114	519	2428	205	25.95	2.54	2.69	1.37	81	5.36	5.6
KK beginning of the experiment												
50% compost + 50% peat	6	28	41	871	153	48.4	3.19	588.6	1.58	54	0.75	6.1
25% compost + 75% peat	2	32	52	1068	183	37.0	2.24	401.3	1.79	46	0.83	6.5
KK end of the experiment												
50% compost + 50% peat	980	70	265	1352	164	64.02	27.68	733.0	1.68	66	4.98	4.0
25% compost + 75% peat	1155	78	340	1677	205	24.7	1.52	195.8	1.68	65	5.91	4.2
EM beginning of the experiment												
50% compost + 50% peat	114	24	37	833	137	46.31	6.10	514.3	1.44	53	1.22	5.6
25% compost + 75% peat	18	29	45	964	172	39.84	2.58	254.2	1.51	54	1.14	6.1
EM end of the experiment												
50% compost + 50% peat	1530	67	285	1604	199	44.55	34.60	734.6	1.35	116	7.76	4.4
25% compost + 75% peat	1045	66	302	1462	182	43.67	24.60	463.25	1.33	72	5.56	4.5
EM + K beginning of the experiment												
50% compost + 50% peat	415	107	89	1413	242	44.55	34.60	734.6	1.35	127	2.75	5.7
25% compost + 75% peat	1045	66	302	1462	718.3	43.43	5.43	463.25	1.80	72	5.56	4.5
EM + K end of the experiment												
50% compost + 50% peat	1855	280	892	2208	338	44.55	34.60	734.6	1.35	242	8.58	4.5
25% compost + 75% peat	1270	190	612	1898	272	46.37	28.91	530.75	1.72	140	6.82	4.5
AL beginning of the experiment												
50% compost + 50% peat	166	30	34	820	130	53.99	9.20	683.62	1.85	54	1.42	5.3
25% compost + 75% peat	5	23	21	917	161	41.80	2.78	452.0	1.55	40	0.81	6.1
AL end of the experiment												
50% compost + 50% peat	1085	69	242	1379	162	63.84	31.70	825.38	1.78	107	5.11	4.1
25% compost + 75% peat	1000	74	280	1531	185	52.64	28.86	553.63	1.68	104	4.90	4.3
AL + K beginning of the experiment												
50% compost + 50% peat	372	137	85	1327	220	46.74	6.86	834.5	2.17	102	2.52	5.5
25% compost + 75% peat	59	75	41	1344	224	35.33	2.34	368.0	1.82	60	1.39	6.3
AL + K end of the experiment												
50% compost + 50% peat	1980	272	853	2117	323	46.88	42.75	817.63	1.60	262	8.80	4.6
25% compost + 75% peat	1350	214	600	1954	282	46.11	29.77	474.00	1.68	170	6.55	4.5

2.3. Morphological Features

The measurements of the following characteristics were taken during the experiment: height and diameter of plants, the number of leaves, the number and diameter of flower heads, number of flower buds, diameter of shoots. The fresh and dry matter were determined. The measurements were carried out when one half of all flower heads was completely developed. The index of leaves greenness SPAD was determined using Yara N-Tester apparatus. For each plant, the index of leaves greenness SPAD measurement was made on three leaves from the middle part of the shoot. The mean sample consisted of 240 leaves per one treatment. This measurement is used to determine the intensity of the leaf green colour and is calculated as a quotient of light absorption connected with chlorophyll presence at the wavelength of 650 nm and the absorption by the leaf tissue at the wavelength of 940 nm. The size of the leaf assimilation area was measured using WinDIAS 3.2 (Delta-T Devices).

2.4. Macronutrients and Micronutrients Determination

Collected samples of substrate were chemically analysed by the universal method. Extraction of macronutrients (N-NH_4, N-NO_3, P, K, Ca, Mg, S-SO_4), Cl and Na was carried out in 0.03 M CH_3COOH with a quantitative 1:10 proportion of substrate to extraction solution. After extraction, the following determinations were made: N-NH_4, N-NO_3—by microdistillation according to Bremer in Starck's modification; P—colorimetrically with ammonium vanadomolybdate; K, Ca, Na—photometrically; Mg—by atomic absorption spectrometry (ASA); S-SO_4—nephelometrically with $BaCl_2$; Cl—nephelometrically with $AgNO_3$. Micronutrients (Fe, Mn, Zn and Cu) were extracted from soil with Lindsay's solution containing in 1 dm^3: 5 g EDTA (ethylenediaminetetraacetic acid); 9 cm^3 of 25% NH_4 solution, 4 g citric acid; 2 g Ca $(CH_3COO)_2 \cdot 2H_2O$. Micronutrients were determined by ASA method. Salinity was identified conductometrically as an electrolytic conductivity (EC in $mS \cdot cm^{-1}$) (substrate:water = 1:2), and pH was determined by potentiometric method (substrate:water = 1:2).

2.5. Statistical Analyses

Results of studies were statistically analysed by ANOVA using Statistica 12.0 software. Homogeneous subsets of the mean were identified by means of Duncan test at the significance level of $p = 0.05$.

3. Results and Discussion

As the results showed, the growth and flowering of the chrysanthemum significantly depended on the type of compost used as well as its percentage share in the substrate. Statistically significant differences in height compared to the control were not observed only in plants with 25% addition of AL and AL + K compost. The lowest height was characteristic for plants grown in a medium consisting of compost without the addition of microbial inoculations. Stunted growth was also observed in plants growing in substrates with 50% compost addition (Table 6). A similar relationship was shown by Zawadzińska et al. [31] in geranium cultivation, where 30 and 40% addition of wood fibres to the substrate resulted in stunted geranium growth. Ornamental plants grown in the substrate enriched with wood products are usually smaller and more compact, which may in fact improve their decorative value [32].

Table 6. The influence of medium on morphological features of chrysanthemum.

Medium		Height of Plants (cm)	Diameter of Plants (cm)	Diameter of Shoot (mm)	Fresh Weight (g)/per pot	Dry Weight (g)/per pot	Diameter of Flower Head (cm)
	Control-peat	13.0 c *	22.7 b	3.0 c	66.7 c	27.3 ab	7.0 bc
KK	25% compost + 75% peat	11.4 a	20.2 a	2.5 a	50.5 b	20.6 a	7.4 c
	50% compost + 50% peat	10.4 a	20.0 a	2.6 ab	47.2 a	20.4 a	6.7 b
AL	25% compost + 75% peat	13.0 c	21.7 a	3.2 d	57.1 b	23.1 a	6.6 b
	50% compost + 50% peat	11.0 a	19.6 a	2.9 b	44.1 a	38.2 b	5.6 a
AL + K	25% compost + 75% peat	13.2 c	23.2 c	2.8 b	62.6 c	45.5 c	7.1 c
	50% compost + 50% peat	12.2 b	22.0 b	2.3 a	55.1 b	41.7 c	7.5 c
EM	25% compost + 75% peat	12.6 b	23.1 c	2.9 b	77.1 d	30.6 b	7.1 c
	50% compost + 50% peat	11.5 a	21.7 a	2.9 b	57.4 b	24.3 a	7.1 c
EM + K	25% compost + 75% peat	12.4 b	22.5 b	3.1 c	77.9 d	31.4 b	7.5 c
	50% compost + 50% peat	11.5 a	21.0 a	3.1 c	64.4 c	26.8 ab	6.7 b

* Means followed by the same letters do not differ significantly at $p = 0.05$.

In the case of plant diameter, wider plants were obtained using a substrate with 25% added AL + K and EM composts. Substrates with the addition of "pure" compost (KK), AL and higher (50%) doses of EM and EM + K composts had a negative effect on the studied trait (Table 6).

Statistical analysis showed that substrates containing EM and EM + K compost had a positive effect on flower head formation. The exceptions were plants that grew in a substrate with 50% added EM + K compost. They did not significantly differ from the control plants (Figure 2). A positive effect of the EM preparation on flowering has been observed in many species, e.g., French marigold, garden geranium, gerbera, rose [33–35]. The lowest number of flower heads was recorded in plants grown in a substrate with 50% addition of AL compost. According to Zawadzińska et al. [31], 40% addition of wood fibres to the substrate caused the formation of fewer inflorescences in geraniums. Wróblewska et al. [36] also reported that high doses (100%, 75% and 50%) of post-consumer wood compost negatively affect flowering of garden geranium. Plants grown in a substrate with 25% addition of EM and EM + K compost showed a significantly higher number of flower buds.

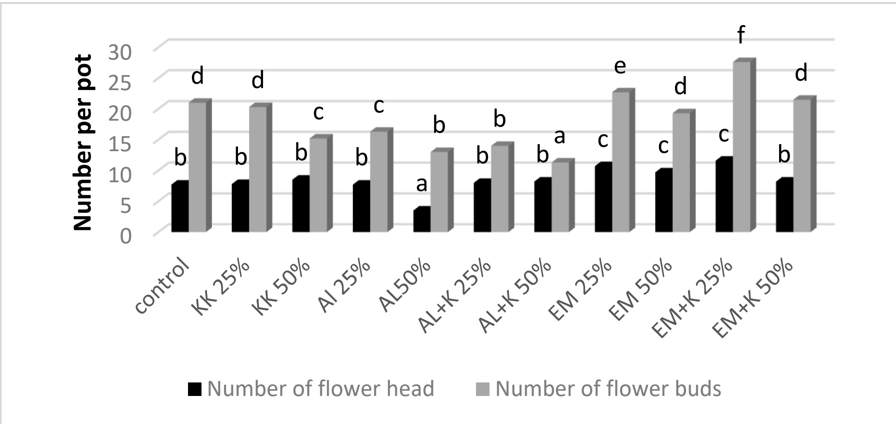

Figure 2. The influence of medium on flowering plants. Means followed by the same letters do not differ significantly at $p = 0.05$.

Inflorescence diameter was negatively affected by the substrate with 50% addition of AL compost. In the remaining cases, statistical analysis did not show significant differences in the studied trait. According to Gariglio et al. [37], 75% addition of willow sawdust to the substrate resulted in smaller flowers in calendula and marigold.

Due to composts, brighter leaves with lower leaf greenness index (SPAD) values were formed (Table 7). Probably the reason could be too low pH of these substrates or high content of Zn, which in excessive amounts may block the uptake of other microelements. The content of N in this studied substrates were relatively high, so the possible reason of lower leaf greenness index could be biological sorption by microorganisms. This could explain the fact that plants grown in a substrate containing 25% compost KK, without the addition of microbiological inoculants had the same SPAD values as the control plants. In spite of lower SPAD values, the visual colour of leaves did not differ compared to the control plants. Similar results were obtained by Schroeter-Zakrzewska et al. [21,33] in garden geranium and canna generalis grown in substrates with the addition of composts prepared from post-consumer wood. Zawadzińska et al. [31] also obtained lower values of leaf greenness index growing geraniums in substrates with 40% addition of wood fibres. Adamczewska-Sowińska et al. [4] observed significantly lower SPAD values in tomato grown in willow wood compost and willow wood compost with the addition of *Peniophora gigantea*.

Table 7. The influence of medium on vegetative features of chrysanthemum.

Medium		Number of Leaves	Greening Index of Leaves (SPAD)	Leaf Area (cm^2)
Control-peat		140.7 c *	51.4 c	12.3 b
KK	25% compost + 75% peat	160.7 d	51.5 c	11.6 a
	50% compost + 50% peat	133.2 b	43.4 a	11.4 a
AL	25% compost + 75% peat	125.2 b	40.2 a	11.8 a
	50% compost + 50% peat	95.5 a	47.1 b	11.7 a
AL + K	25% compost + 75% peat	137.2 b	41.5 a	12.5 b
	50% compost + 50% peat	138.2 b	42.1 a	12.1 b
EM	25% compost + 75% peat	76.8 a	48.5 b	14.4 c
	50% compost + 50% peat	156.2 d	49.0 b	14.9 cd
EM + K	25% compost + 75% peat	156.7 d	48.9 b	14.7 cd
	50% compost + 50% peat	138.0 b	46.8 b	14.0 c

* Means followed by the same letters do not differ significantly at $p = 0.05$.

Plants grown in the substrate with 25% EM and EM + K composts had a higher above-ground fresh weight. This was correlated with the larger leaf area that formed on these plants. The addition of 25% AL + K and 50% EM + K composts did not cause significant changes in fresh weight. In other cases, the above-ground part of the plants was significantly lighter compared to the control plants (Table 7). According to Brito et al. [38], the addition of acacia compost to the substrate affected the increase of fresh and dry weight of lettuce. However, Zawadzińska et al. [31] claims that the higher the proportion of wood fibres in the substrate the lower the fresh weight of the above-ground part of the geranium. The study by Murphy et al. [39] found that 25 and 50% addition of wood fibres from different tree species to peat reduced the dry weight of petunia and periwinkle. In the case of lettuce cultivation, a higher crop yield (higher weight) was obtained when using compost consisting of willow wood, green waste and nitrogen addition [40].

The number of leaves formed on plants significantly depended on the substrate used. More leaves, on average by 15–20 as compared to control plants, were formed on plants grown in substrates with 25% addition of (KK) and EM + K composts as well as with 50% addition of EM compost (Table 6). In other cases, fewer leaves formed on the plants. An increase in the number of leaves after using substrates with post-consumer wood composts was also observed in garden geraniums [21]. Wolna-Maruwka et al. [34] also showed a positive effect of the foliar and soil EM microbial inoculation on the number of leaves of French marigold grown in peat. The negative effect of pecan wood on chrysanthemum leaf number was observed by Picchioni et al. [41]. These authors report that the addition of nitrogen to a medium containing pecan wood contributes to an increase in both leaf number and leaf area.

Shoot diameter was not significantly affected by the substrates with the 25% addition of AL and EM + K composts. In other cases, the shoot diameter was slightly smaller compared to that of the control plants (Table 6). Analysing the leaf area, a clear effect of the use of substrates with added composts containing the EM microbial inoculation was observed, irrespective of the dose of compost. In comparison to control plants, smaller leaf blades were formed when substrates containing KK and AL composts were used (Table 7). According to Wróblewska et al. [19], cultivation in 100% compost and the use of substrates with 75% and 50% addition of post-consumer wood composts negatively affected the leaf area of canna generalis.

The quality of plants shown Figures 3–5.

Figure 3. The quality of chrysanthemum (KONTROLA-control, KK 25% + TORF 75%-compost KK 25% + peat 75%, EM 25% + 75% TORF-compost EM 25% + peat 75%, EM + K 25% + 75% TORF-compost EM + 25% + peat 75%).

Figure 4. The quality of chrysanthemum (KONTROLA-control, KK 50% + TORF 50%-compost KK 50% + peat 50%, EM 50% + 50% TORF-compost EM 50% + peat 50%, EM + K 50% + 50% TORF-compost EM + 50% + peat 50%).

Figure 5. The quality of chrysanthemum (KONTROLA-control, AL 25% + TORF 75%-compost AL 25% + peat 75%, AL 50% + 50% TORF-compost AL 50% + peat 50%, AL + K 25% + 75% TORF-compost AL + K 25% + peat 75%, AL + K 50% + 50% TORF-compost AL + K 50% + peat 50%).

4. Conclusions

The studied composts obtained in bioreactors from post-consumer wood-based material waste and production wood-based material waste had a significant effect on plant development and appearance. Plant quality depended on the dose of compost used as well as on the type of microbial inoculations used during the composting process. Plant height was negatively affected by the substrates used. Despite statistical differences, plants grown in media with added composts visually did not differ from control plants. Plants grown in substrates with the 25% addition of AL and AL + K composts were an exception. In this case, the plants obtained were less flowering. Chrysanthemum is an ornamental species with flowers, therefore the basic parameter when assessing the quality of plants is the number of flowers and buds developing on the plant. The use of Activit Las in the composting process had a negative or neutral effect on the flowering of the plants. The addition of composts containing the EM microbial inoculation to peat stimulated the formation of inflorescences and inflorescence buds. It also had a positive effect on the size and number of leaves. Our research demonstrated that compost from post-consumer wood especially containing microbiological inoculum EM and EM + K can constitute a 25% addition to peat in chrysanthemum cultivation.

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