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BIOCOMPOST VALORIZATION IN THE CONTEXT OF THE CIRCULAR ECONOMY; CASE STUDY IN ORNAMENTAL PLANTS

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Abstract

The study analyzed the possibility of capitalizing compost resulting from fermentable organic waste, for the purpose of growing plants. To prepare the growth substrates, compost (Comp) was used in a single variant (V2), as well as in a mixture with peat (Pea) and vermiculite (Ver). Depending on the weight in the mixture (% in volume), the experimental variants resulted: variant V3 – Comp:Pea:Ver, 20:70:10; variant V4 – Comp:Pea:Ver, 30:60:10; variant V5 – Comp:Pea:Ver, 40:50:10. For comparison, a control variant (V1) based on garden soil (GS) was used. The biological material was represented by the species Tagetes patula Durango® Tangerine. The experiment was done on pots. Vegetative parameters, tagetes shoots diameter (TsD), tagetes shoots number (TsN), tagetes plant height (TpH), tagetes plants diameter (TpD) were determined and the ratio TpH/TpD was calculated; floral quality indices, tagetes inflorescence number (TiN), tagetes inflorescence diameter (TiD). The determinations were made during the vegetation period, at six different times, T1 to T6, between March and October. Correlations were identified between the considered parameters and indices. Based on the PCA, the common orientation of the vegetative parameter TpD with the index of floral quality TiD, respectively of the parameter TpH with TiN was found. PC1 explained 45.648% of variance, and PC2 explained 22.774% of variance. Scaling dendrogram resulted for variant classification. Mathematical models resulted through regression analysis, which described the variation of floral quality indices (TiN and TiD) in relation to vegetative parameters, with 3D graphic representation and in the form of isoquants.

Key words: *circular economy, compost, growth substrate, models, Tagetes*

INTRODUCTION

The circular economy is considered as an effective tool in the context of sustainable development [1]. The circular economy appeared as a potential solution, starting from a concept based on technology to generate economic gains and through the balanced exploitation of resources [27].

Some researchers [4] found how the circular economy has become a popular paradigm in the political and business sphere, and highlighted positive aspects but also some potential shortcomings (reduced impact by focusing on incremental innovations, generating some negative effects).

Morone and Imbert (2020) [14] considered that the circular bioeconomy must rely as much as possible on waste and residual raw materials in order to be socially accepted, and in this way it would reduce dependence and pressure on crops.

In the context of the circular economy, certain categories of waste (e.g. food waste) represent an important residual raw material, which can be converted into biofuels, bioplastics [14]. The fermentable waste that comes from human activities (anthropic ecosystems) represents a residual raw material that can be converted into different types of products such as biofuels, bioplastics, biocompost, etc. [14, 21].

Organic waste represents a source with high potential of renewable energy, with processing under controlled conditions (anaerobic digestion), a fact that facilitates energy recovery and reducing the impact on the environment [9]. An alternative to anaerobic digestion is the composting of some categories of fermentable waste, in relation to the properties of organic waste and the quantification of energy consumption, in balance with the beneficial ecological, economic and social effects.

In addition to reducing food waste, attracting food waste as residual raw materials and valorizing it through different processing methods in the circular economy is of great interest [16, 19, 22].

The bioconversion of waste is seen as a sustainable means of valorizing resources from the perspectives of population growth and the growing need for energy [3]. In the management of organic waste, composting has been recognized as a dual technology [21]. As the circular economy is based on innovative technologies, waste composting is a technology that practically integrates into the valorization of residual raw materials, thus changing the paradigm "from waste to resources" [21].

Depending on the type and properties of fermentable organic waste, considered for composting, the major components present in the organic matter (C, N, P, K) were studied, different procedures for improving the final product, respectively compost, by adding some ingredients in the process composting (e.g. organo-mineral components, or minerals) [2, 18, 21]. Fermentation installations and methods were also tested, as well as analytical installations to monitor the process [7, 26]. Different physical, chemical, biological or microbiological testing methods were used to evaluate the quality of the final product (compost), but "in situ" testing with test plant species showed high interest [18]. An integrated approach and "multi-stakeholder" cooperation have proven to be beneficial in the success of the valorization of fermentable organic waste through composting [13].

Plant crops systems have the ability to utilize, in the form of compost, different categories of organic or mineral waste, originating from other sectors of the economy [5, 15].

In urban ecosystems, green spaces require different types of substrate, in relation to the quality of the soil, of the developed land, but also the ecophysiological conquests of ornamental plant species [8, 24]. Compost can represent a dominant component for making substrates, to which other organic, mineral or organo-mineral components can be added.

The circular economy takes into account the valorization of waste and the integration of the resulting products in a balanced way in the "ecological - economic - social" triad.

In this context, the present study tested the compost resulting from the recycling of some fermentable organic waste, together with other components, as substrates for plant growth, and described through mathematical and statistical methods the variation of some vegetative parameters and indices of floral quality in the biological material.

MATERIALS AND METHODS

The study analyzed the possibility of using a compost product in the cultivation of ornamental plants, in the context of the circular economy.

The compost was obtained from the fermentation of fermentable organic waste (FOW) currently collected at the urban locality level (e.g. Oradea Municipality). The organic waste was fermented in a controlled manner through a composting process (CP), within our ecological platform (Municipality of Oradea).

The compost (Comp) was used in different variants (alone – V2), or mixed with other components for growth substrates, such as peat (Pea), and vermiculite (Ver). Depending on the weight in the mixture (components in the mixture, in %), the experimental variants resulted: Comp:Pea:Ver (20:70:10), variant V3; Comp:Pea:Ver (30:60:10), variant V4; Comp:Pea:Ver (40:50:10), variant V5. For comparison, a control variant was used, with the substrate based on garden soil (V1), figure 1. The experiment was organized in pots, Salonta Locality, Bihor County.

The biological material was represented by the species *Tagetes patula* Durango® Tangerine. A species was chosen that lends itself to being cultivated on different growth substrates, in conditions of open spaces, but also in protected spaces. At the same time, *Tagetes* is a species with multiple valences of use for ornamental, pharmaceutical and medicinal purposes (based on the active principles), cosmetics, as well as for food purposes [6, 17].

To evaluate the growth and development of plants in relation to the growth substrate, a series of vegetative (physiological) plant parameters were evaluated: Tagetes shoots diameter (TsD), tagetes shoots number (TsN), tagetes plant height (TpH), tagetes plants diameter (TpD) and the TpH/TpD ratio was calculated.

Floral quality indices were used to evaluate the inflorescences: tagetes inflorescence number (TiN), tagetes inflorescence diameter (TiD). The determination of the considered parameters and indexes was done monthly, at six different times (T1 to T6), evolving during the vegetation period, in the interval April - October.

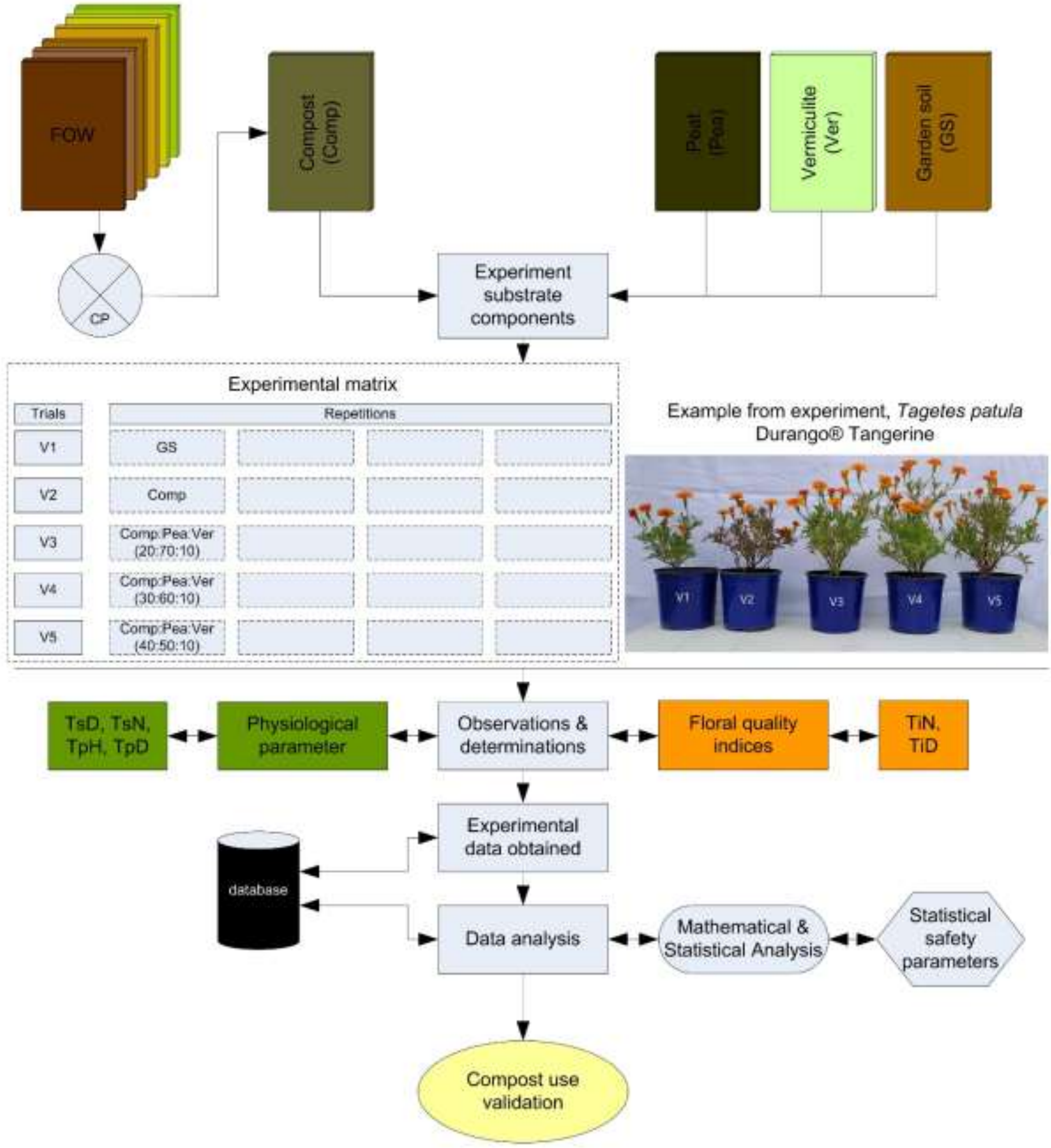


Fig. 1. Experimental flow chart
Source: Original figure.

The recorded experimental data were analyzed for statistical reliability, the presence of variance, the time variation of the studied parameters and indices, the distribution of the variants in relation to the recorded indices, the variation of floral quality indices in relation to vegetative parameters, in the study conditions. Appropriate mathematical and statistical analysis tools were used [10, 12, 28]. A flow chart designed by the authors, shown in Figure 1, was used to conduct the study.

RESULTS AND DISCUSSIONS

Physiological parameters (TsD, TsN, TpH, TpD) and floral quality indices (TiN, TiD) in *Tagetes patula* were determined at six different times, between April 22 and October 22, and the recorded values are presented in Table 1.

The test Anova confirmed the statistical reliability of the data and statistical reliability in the set of recorded experimental data ($p<0.001$, F > Fcrit; Alpha=0.001), Table 2.

Table 1. Values of the parameters of *Tagetes patula* Durango® Tangerine in the experimental conditions

Trial	TsD	TsN	TpH	TpD	TpH/TpD	TiN	TiD
	(mm)	(no.)	(cm)	(cm)		(no.)	(cm)
V1-T1	3.50	9.25	20.38	13.13	1.55	1.00	3.81
V2-T1	6.50	26.75	26.38	24.88	1.06	3.75	5.82
V3-T1	6.75	22.50	29.13	25.75	1.13	3.25	5.86
V4-T1	7.00	22.50	29.00	25.25	1.15	3.75	5.92
V5-T1	7.13	22.25	28.38	25.50	1.11	3.75	6.03
V1-T2	4.20	21.50	25.38	20.95	1.21	2.75	4.62
V2-T2	6.90	40.25	28.00	27.00	1.04	2.50	4.75
V3-T2	7.38	38.00	34.38	26.38	1.30	5.25	5.34
V4-T2	7.88	42.00	35.38	28.88	1.23	4.25	4.96
V5-T2	7.75	45.00	30.63	27.25	1.12	3.75	5.21
V1-T3	4.50	28.50	26.00	22.38	1.16	1.75	4.24
V2-T3	8.00	27.00	19.50	17.50	1.11	1.00	4.10
V3-T3	7.75	58.00	32.50	28.50	1.14	4.00	4.64
V4-T3	8.13	60.50	34.13	29.00	1.18	4.50	4.18
V5-T3	8.00	60.25	30.50	28.50	1.07	6.25	4.52
V1-T4	4.63	15.50	22.00	14.78	1.49	1.00	3.70
V2-T4	7.50	25.00	22.75	22.00	1.03	2.00	4.05
V3-T4	7.38	25.25	29.00	21.75	1.33	5.25	3.68
V4-T4	8.00	24.00	29.00	26.00	1.12	1.00	3.20
V5-T4	8.25	22.50	22.00	22.50	0.98	0.50	4.10
V1-T5	4.67	30.33	23.67	22.83	1.04	5.00	4.32
V2-T5	7.50	32.00	22.00	31.00	0.71	4.50	7.23
V3-T5	7.00	29.00	33.00	26.50	1.25	5.00	4.08
V4-T5	10.00	29.00	32.00	34.00	0.94	6.00	5.13
V5-T5	8.50	31.00	28.00	33.00	0.85	5.00	4.13
V1-T6	4.83	34.67	23.17	25.83	0.90	5.33	4.36
V2-T6	7.75	34.00	23.25	7.75	3.00	7.50	4.77
V3-T6	7.75	26.50	31.50	7.75	4.06	3.50	4.23
V4-T6	9.50	33.00	28.00	9.50	2.95	4.00	5.07
V5-T6	8.50	29.00	27.50	8.50	3.24	6.00	4.20
SE	±0.29	±2.20	±0.80	±1.34	±0.14	±0.33	±0.16

Source: Original data from the experiment.

Table 2. Anova test values

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	28950.91	6	4825.152	149.4423	1.18E-71	3.917582
Within Groups	6554.408	203	32.28772			
Total	35505.32	209				

Source: Original data, calculation results.

The correlation analysis led to the values presented in table 3, under statistical safety conditions ($p<0.05$; $p<0.01$). A strong, negative correlation was recorded between TpD and the TpH/TpD ratio (r=-0.838***), weak correlation between Tsn and TpH (r=0.555**). Correlations of low intensity were recorded between other determined parameters, under conditions of statistical safety.

Table 3. Correlation table

Variable		TsD	TsN	TpH	TpD	TpH/TpD	TiN	TiD
TsD	Pearson's r	—						
	p-value	—						
TsN	Pearson's r	0.390*	—					
	p-value	0.033	—					
TpH	Pearson's r	0.447*	0.555**	—				
	p-value	0.013	0.001	—				
TpD	Pearson's r	0.149	0.387*	0.390*	—			
	p-value	0.432	0.034	0.033	—			
TpH/TpD	Pearson's r	0.202	-0.096	0.062	-0.838***	—		
	p-value	0.283	0.614	0.744	< .001	—		
TiN	Pearson's r	0.342	0.466**	0.424*	0.118	0.216	—	
	p-value	0.064	0.009	0.019	0.536	0.251	—	
TiD	Pearson's r	0.151	0.090	0.117	0.304	-0.157	0.285	—
	p-value	0.425	0.638	0.539	0.102	0.407	0.126	—

* p < .05, ** p < .01, *** p < .001

Source: Original data.

According to the PCA, the diagram in Figure 2 resulted, in which the variants were distributed in relation to the contribution to the achievement of the vegetative parameters and the evaluated physiological indices (I will plot in the PCA diagram).

It was found, first of all, the common orientation of the vegetative parameter TpD with the index of floral quality TiD, respectively of the parameter TpH with TiN. The experimental variants were distributed differently in relation to the considered parameters and indexes. PC1 explained 45.648% of variance, and PC2 explained 22.774% of variance).

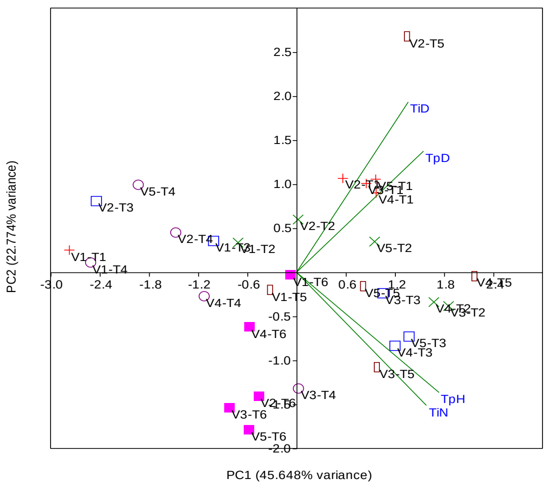


Fig. 2. PCA diagram regarding the experimental variants of *Tagetes patula* in relation to the considered parameters and indices

Source: Original figure.

The experimental variants were ranked, based on Ranking-Scaling, in relation to vegetative parameters (TpD, TpH) and floral quality indices (TiN, TiD) considering the values recorded during the vegetation period, and the six moments of determination, Figure 3.

The variation in the number of inflorescences, as floral quality index (TiN), was evaluated by regression analysis and the result was equation (1) as a general model of variation (Multiple R=0.507). The graphic distribution of TiN variation in relation to TsD (x-axis) and TpH (y-axes) is presented in figure 4.

$$\mathrm{TiN} = a\,x^2 + b\,y^2 + c\,x + d\,y + ex\,y + f \qquad (1)$$

where:
TiN – Tagetes inflorescence number (no.); x – TsD – Tagetes shoot diameter (mm); y – TpH – Tagetes plant height (cm); a, b, c, d, e, f – coefficients of the equation (1); a= -0.12229550; b= -0.01996708;
c= -0.47033993; d= 0.52756729;
e= 0.09256904; f= -3.82428478.

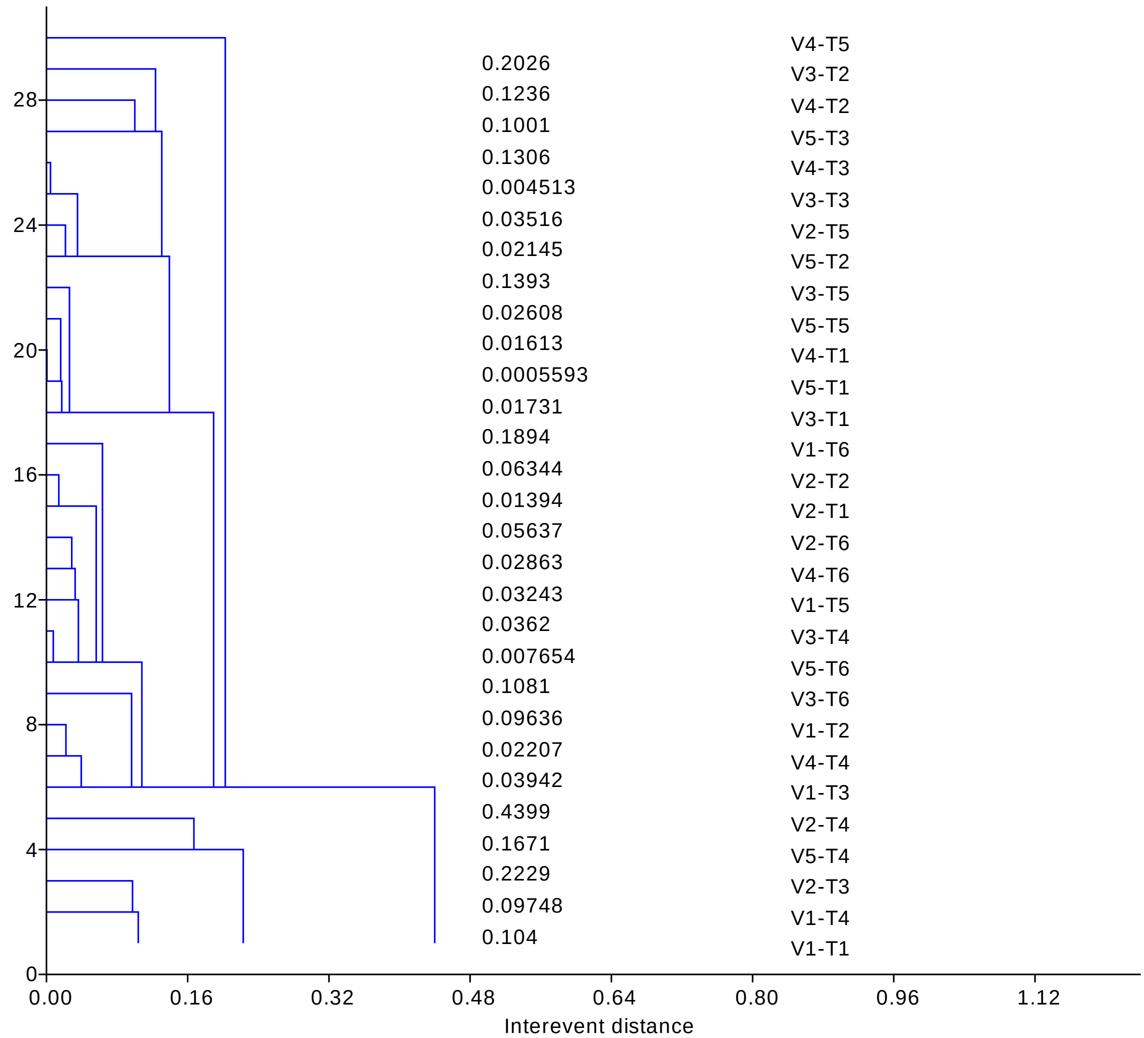
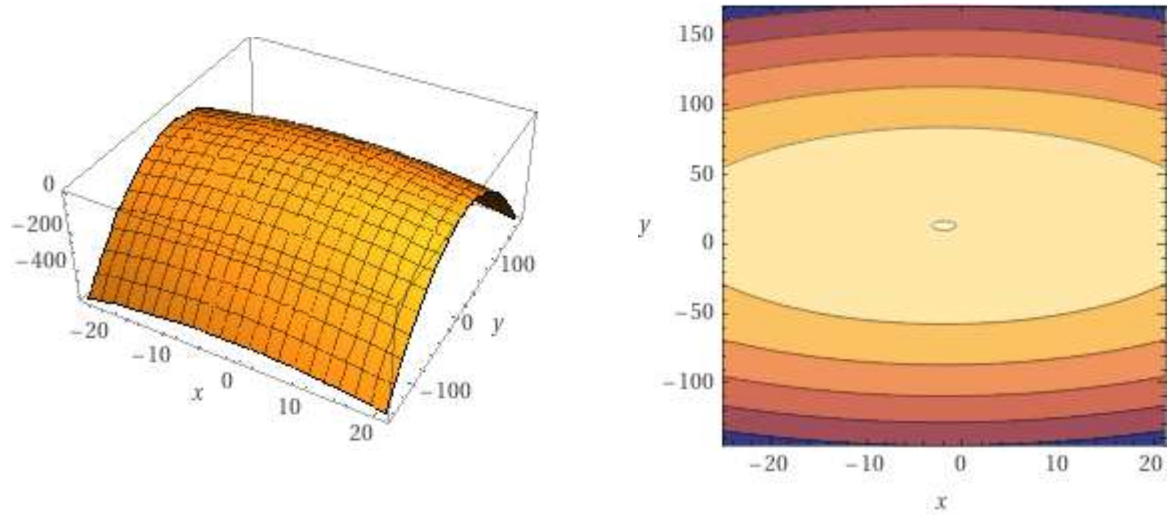


Fig 3. Scaling dendrogram for the experimental variants
Source: Original figure.



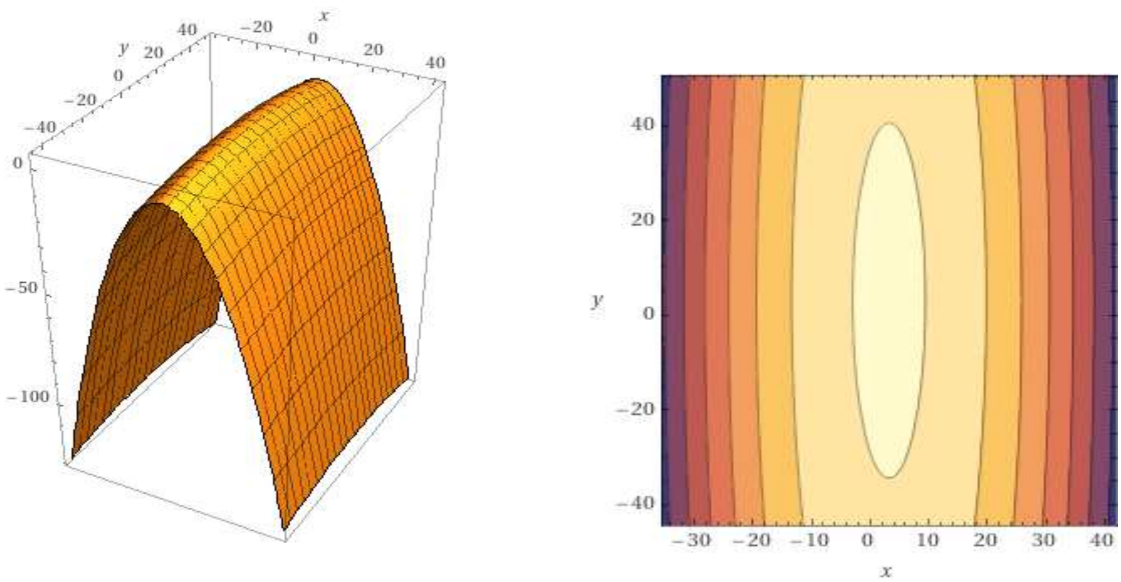
(a) (b)

Fig. 4. Spatial distribution of the TiN index in relation to TsD (x-axis) and TpH (y-axes)
Source: Original figure.

Inflorescence diameter variation, as floral quality index (TiD), was described by equation (2) as a general model of variation, in conditions of Multiple R=0.377 in relation to TsD and TsN, respectively in conditions of Multiple R=0.451 in relationship with TpH and TpD. The graphic distribution of the variation of TiD in relation to TsD (x-axis) and TsN (y-axes) is presented in Figure 5, and the variation of TiD in relation to TpH and TpD is presented in Figure 6.

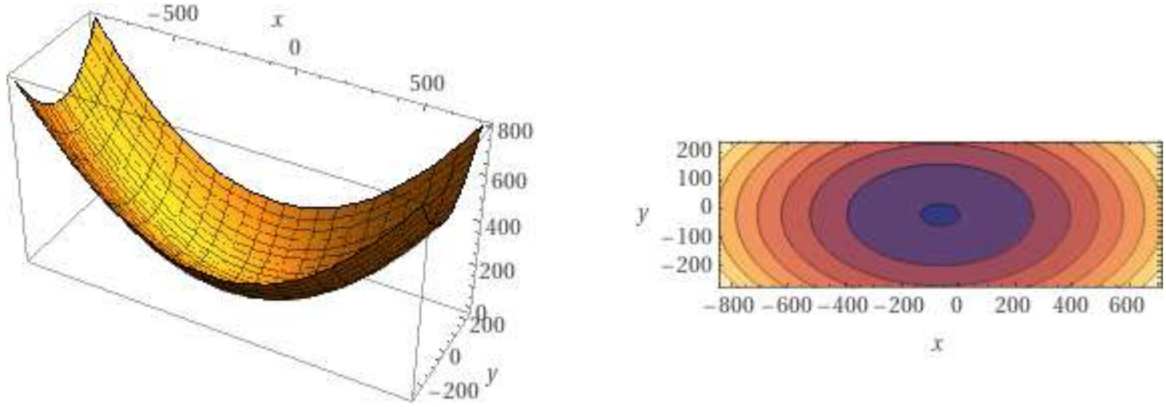
$$\mathrm{TiD} = \mathrm{a}\,x^2 + \mathrm{b}\,y^2 + \mathrm{c}\,x + \mathrm{d}\,y + \mathrm{e}x\,y + \mathrm{f} \qquad (2)$$

where:
TiD – Tagetes inflorescence diameter (cm); *x* – TsD – Tagetes shoot diameter (mm); *x* – TpH – Tagetes plant height (cm); *y* – TsN – Tagetes shoot number (cm); *y* – TpD – Tagetes plant Diameter (cm); a, b, c, d, e, f – coefficients of the equation (2); values in relation to TsD and TsN: a= -0.12229550; b= -0.01996708; c=-0.47033993; d= 0.52756729; e=0.09256904;f=-3.82428478; values in relation to TpH and TpD: a= 0.00098191; b= 0.00334110; c= 0.12681571; d= 0.14228610; e= -0.00856014;f= 0.74208576.



(a) (b)

Fig. 5. TiD variation in relation to TsD (x-axis) and TsN (y-axes)
Source: Original figure.



(a) (b)

Fig. 6. TiD variation in relation to TpH (x-axis) and TpD (y-axis)
Source: Original figure.

The differences generated by variants V2 to V5 compared to variant V1 (control) were calculated. The calculations resulted in different values of the growth rate (Δ) generated by the growth substrate, depending on the analyzed parameters. In the case of ΔTsD, positive values were recorded for all variants and for the entire study period (March - October) in relation to V1, values between 2.33 - 5.33 mm. In the case of ΔTsN, positive values were recorded (in the first part of the vegetation period T1 to T4), but also negative values, especially in the last months of the vegetation period (T5 - T6). In the case of ΔTpH, positive increases were recorded with the exception of the V2T3 and V2T5 variants. In the case of ΔTpD, positive increases were recorded in the case of the first five determination moments (T1 to T5, except V2T3) and negative values at the T6 determination moment. In the case of ΔTiN, positive increases were recorded in most variants, with some exceptions (V2T2, V2T3, V5T4, V2T5, V3T6 and V4T6). In the case of ΔTiD, positive increases were also recorded, with some exceptions for certain variants and determining moments (V2T3, V4T3, V3T4, V4T4, V3T5, V5T5V3T6 and V5T6). The graphic distribution of the increase calculated for all cases is presented in Figure 7.

Fermentable organic residues represent a rich source of nutrients and organic matter, so necessary for the soil, by composting their nutritional value increases for the soil and plants and can be used as an organic fertilizer or as a component for different growth substrates [20]. The use in agriculture (horticulture, forestry) of composts resulting from municipal solid organic waste has also been studied from ecological and environmental protection perspectives, in the sense of improving the composting process and reducing the impact [25].

Sayara et al. (2020) [23] considered composting to be a technology that can be implemented at any scale, both in large, industrial plants and at family level, of course with some differences regarding the categories of waste components, work facilities, performance and composting yield to. Imran et al. (2022) [11] reported an increase in chlorophyll content (≈35%), biomass (≈25%) and yield (75%) in vegetable species through the use of compost.

Associated with better nutrition, the authors of the study recorded an increase in the content of mineral elements in the samples of the studied vegetable species (hot peppers, tomatoes).

Composting technology, composting parameters and optimal composting conditions, evaluation criteria, conversion processes of organic matter and some mineral elements (e.g. P) were studied to optimize, reduce the impact on the environment and increase the efficiency of compost as a product [29].

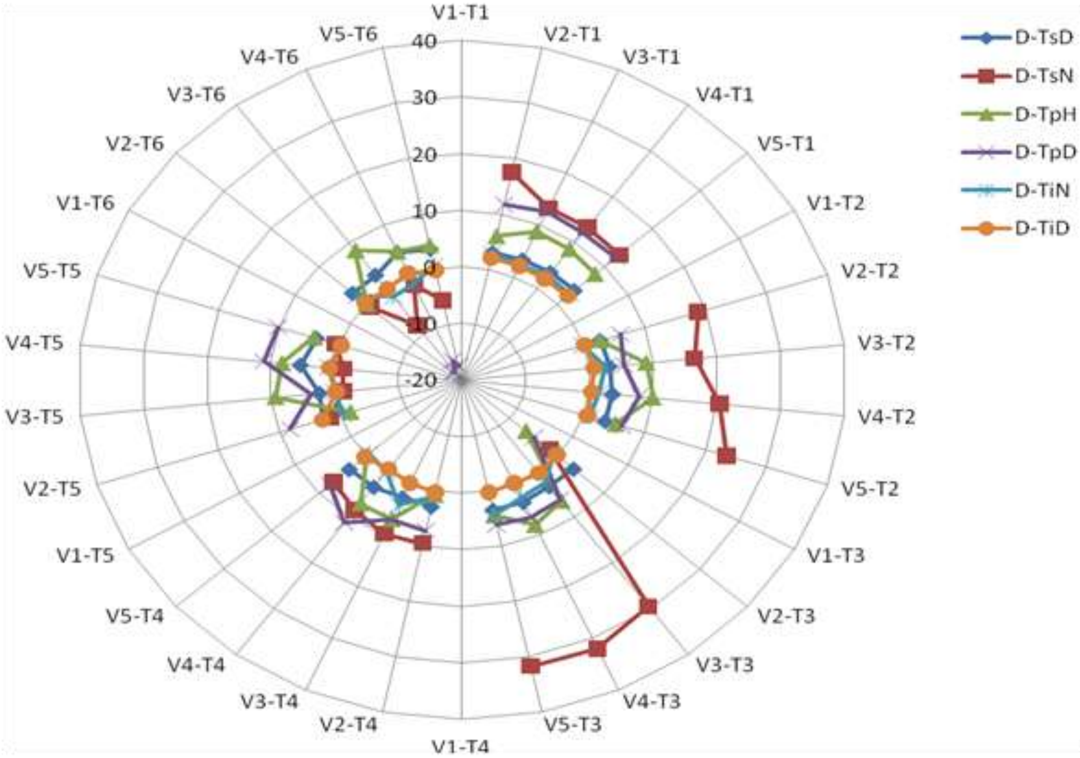


Fig. 7. Graphic representation of the calculated Δ values
Source: Original figure.

The present study was also included in this context, to evaluate the effect of a compost resulting from the fermentation of fermentable urban waste, in the culture of ornamental plants, and the results provided show the potential of the compost as well as some shortcomings in the study conditions. The results recorded, analyzed and properly interpreted can provide an information base for other similar studies, with theoretical, scientific and practical applicability.

CONCLUSIONS

The compost resulting from the fermentation of organic waste, used alone and in combination with peat and vermiculite ensured the obtaining of favorable substrates for the growth of ornamental plants, *Tagetes patula* Durango® Tangerine.

Physiological parameters (TsD, TsN, TpH, TpD) and floral quality indices (TiN, TiD) showed variable dynamics during the study period, in relation to the specifics of each parameter and the experimental variants.

Correlations varying in intensity between the studied parameters were recorded. According to PCA, the common orientation of the vegetative parameter TpD with the index of floral quality TiD, respectively of the parameter TpH with TiN was found. The experimental variants were distributed differently in relation to the considered parameters and indexes. PC1 explained 45.648% of variance, and PC2 explained 22.774% of variance).

The ranking of the variants was obtained, of the Ranking-Scaling type, in relation to vegetative parameters (TpD, TpH) and floral quality indices (TiN, TiD).

Equation-type models, and 3D and isoquant graphic models resulted from the regression analysis, and described the variation of floral quality indices (TiN, TiD) in relation to vegetative parameters, under the study conditions under the influence of growth sub-treatments.

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