Industrial Crops & Products 192 (2023) 116093

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Productivity and flower quality of different pot marigold (*Calendula officinalis* L.) varieties on the compost produced from medicinal plant waste

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ARTICLE INFO

Keywords:
Pot marigold
Medicinal plant waste
Compost
Varieties
Productive parameters
Qualitative parameters

ABSTRACT

This article describes still insufficiently known technology of pot marigold cultivation with the compost produced from the organic waste of the processing of medicinal plants. For the first time the application was analyzed of different amounts of compost (control – without compost, 2, 10 and 30 kg/m^2) on the morphological, productive and qualitative parameters of two pot marigold varieties (*Domaći oranž* and *Plamen Plus*). During the five-year period, the best results in both tested pot marigold varieties were achieved with the 30 kg/m^2 compost application. The yield of dry flower was higher for the *Domaći oranž* pot marigold variety fertilized with 30 kg/m^2 compost (1957.4 kg/ha) compared with the *Plamen Plus* variety (451.1 kg/ha). A significantly higher fresh flower yield of the *Domaći oranž* variety greatly influenced the increase in the quantities of examined quality parameters (total carotenoids, total phenolic, total flavonoids, and DPPH reduction), whose content was higher in the *Plamen Plus* variety. The artificial neural network model, was built applying the Broyden-Fletcher-Goldfarb-Shanno algorithm, exerted the adequate forecasting abilities for the productivity and quality of pot marigold flowers and the influence of compost material, produced from medicinal plants waste (R^2 was 0.837 for the training period). This research demonstrates that it is possible to use organic waste obtained in the processing of medicinal plants, supporting the effectiveness of a circular economy model in the cultivation of pot marigold.

1. Introduction

Pot marigold (*Calendula officinalis* L.) is an annual cultivated herbaceous plant belonging to the aster family (Asteraceae). Official use includes dried pot marigold flower (*Calendulae flos*) and its dried petals (*Calendulae flos sine calycibus*) (Dános, 2006). In the last few years, it has become a highly sought-after raw material on global and domestic markets due to its wide application in the pharmaceutical and cosmetic industries (EMEA, 2008; Re et al., 2009; Tucakov, 2014). The pot marigold plant is widely used in the organic production where, in addition to its phytocidal and insecticidal effect, its above ground biomass is utilized as waste in the composting process. In order to provide enough quality raw material, it is important to examine various agrotechnical and agroecological factors of pot marigold production that affect its morphological, productive, and qualitative parameters (Piccaglia et al., 1997; Berti et al., 2003; Salamon et al., 2006; Gomes et al., 2007; Crnobarac et al., 2008).

One of the important areas of agrotechnical research is the mineral nutrition of pot marigold which is mainly conducted with commercial nutrients with different formulations (Atiyeh et al., 2002; Naguib et al., 2005; Khalid et al., 2006; Bi et al., 2010; Cox and Eaton, 2011; Król, 2011a, 2011b; Bielski and Szwejkowska, 2013; Hosenpor et al., 2013;

Abbreviations: H, Plant height; MWP, Mass of the whole plant; NFP, Number of flowers on plant; AMF, The average mass of the flower; MFP, Mass of flowers per plant; DF, Flower diameter; FY, Fresh flower yield; DY, Dry flower yield; TC, total carotenoids; TP, total phenolic; TF, total flavonoids; DPPH, DPPH reduction.

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https://doi.org/10.1016/j.indcrop.2022.116093
Received 5 August 2022; Received in revised form 26 November 2022; Accepted 3 December 2022

Panah and Vash, 2014). However, research has been recently intensified on certain organic fertilizers, soil improvers, biostimulants, PGPR mediated bioinoculants, etc. (Bhat and Limaye, 2012; Elhindi, 2012; Shokrani et al., 2012; Ali, 2013; Anderson, 2013; Hasan et al., 2014; Sardoei, 2014; Rafiee et al., 2015; Mulk et al., 2022; Nawaz et al., 2022).

During collection, production, and processing of aromatic and medicinal plants (MAPs), a significant amount of biowaste is generated, which, in previous practice, used to be disposed of in landfills and other inadequate areas, together with inorganic waste and/or contaminated hazardous substances (Amir et al., 2005; Cai et al., 2007; Brändli et al., 2007). Over-use of fertilizers in crop production increases environmental pollution and affects ecosystems in negative ways, therefore adding organic matter in the form of compost is a good strategy that promotes crop production with minimal environmental pollution (Khodadadi et al., 2013). The high importance of compost in both ecological and economic sense, justifies composting as one of the methods of biological treatment. Composting is recommended as a tool for managing and controlling diseases, pests, and weeds. In organic production, it is desirable that all organic waste from the farm is composted and as such returned to the soil as technologically mature compost (Khan et al., 2019). Such compost has significant commercial potential in horticultural production of flowers, vegetables, and medicinal plants, primarily in container production of seedlings (as an integral part of substrate mixtures), but also, in field conditions, where it can be achieved by using compost produced in the medicinal plants production (Khalid and da Silva, 2012). Saha and Basak (2020), confirmed that the fresh waste obtained in the processing of medicinal and aromatic plants are cheaper materials for plant nutrition than rock phosphate and manure, and it has sufficient N, P, and K elements. During processing, plants like basil, rosemary and sage can produce quality compost. This compost can be successfully applied for the restoration and maintenance of soil fertility (Zaccardelli et al., 2021).

The objective of this work was to study the possibility of predicting the productivity and quality of flowers of two pot marigold varieties based on the compost material, produced from waste of medicinal plants, using the artificial neural network (ANN) for mathematical modeling.

2. Material and methods

2.1. Plant material

Two varieties of pot marigold (*Calendula officinalis* L.) were compared in this study: the *Domaći oranž* variety (produced in Institute for Medicinal Plant Research “Dr Josif Pančić” from Belgrade, Serbia), and the *Plamen Plus* variety (produced by the Semo Company from Smržice (Czech Republic) in Pančevo (44°52’20"N; 20°42’06"E; 74 m.a.s.l.)) during the period 2013–2017.

2.2. Meteorological data

Meteorological data was obtained from the weather station of the “Tamiš” Institute, Pančevo (Fig. 1).

Pot marigold seed germinate between 2 and 32 °C with the optimum temperature for germination at 16–17 °C (Eberle et al., 2014). During 2013 and 2015, a very pronounced lack of precipitation was recorded in

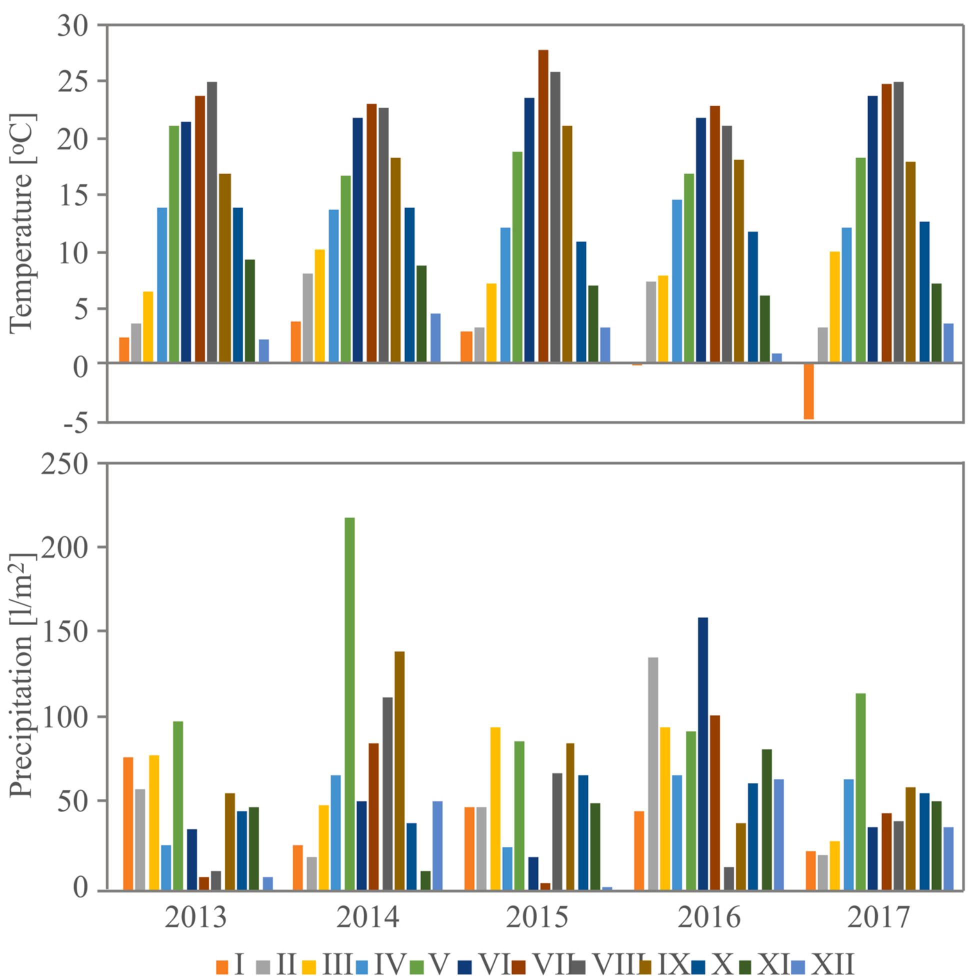

Fig. 1. Meteorological data for period in 2013–2017.

June and July, further aggravated by high temperatures that negatively affected the growth and development of pot marigold plants (Fig. 1). Such weather conditions contribute to the lush increase in the above ground biomass and the development of the root system in the surface part of the soil, and such plants react extremely adversely to water deficiency during the second part of the vegetation period. Drier than normal conditions in April and May delayed plant emergence, and heavy rainfall in July and August extended the period of flowering and seed maturation (Król and Paszko, 2017). Combining the precipitation and temperature data, it can be noted that 2016 was the most favorable year for pot marigold growth and development.

2.3. Field experiment

During the experiment, the flaxseed medicinal plant species (*Linum usitatissimum* L.) was used as the pre-crop on the experimental plot. The experiment was conducted on humogley soil type. This soil has the following agrochemical characteristics: pH value = 5.4, hummus content = 2.3 %, P_2O_5 content = 3,6 mg/100 g soil, and K_2O = 36.2 mg/100 g soil. The experiment was based on a completely random block system, with the basic parcels 10.0 m^2 in size (5.0 m × 2.0 m), in four repetitions. The compost was created from medicinal plant waste at the Institute for Medicinal Plant Research "Dr Josif Pančić" and contained 2.2 % N, 0.46 % P_2O_5, 0.48 % K_2O, 0.6 % Fe, 0.08 % Zn, and 26 % organic matter. The entire amount of compost was applied immediately before the sowing, at different times across years due to meteorological conditions. In the first year (the year 2013), the sowing was performed on April 3, in the second year (the year 2014), on April 2, in the third year (the year 2015), on April 10, in the fourth (the year 2016), on April 1, and in the last, fifth, year (the year 2017), on March 27. The sowing was done manually in continuous rows with a 50 cm inter-row spacing. In the first treatment 2 kg/m^2 of compost was applied, 10 kg/m^2 to the second treatment, and 30 kg/m^2 to the third treatment. No compost was applied to the control treatment.

Standard maintenance measures were applied during the vegetation season. The weeds were destroyed mechanically without the use of herbicides. In all five years, preventive treatment was performed against powdery mildew before the emergence of flower buds (*Podosphaera xanthii* (Castagne) Brown & Shishkoff (formerly *Sphaerotheca fuliginea*)) with the Chitosan preparation (0.4 %). Biological treatment was also performed against cotton bollworm with Chitosan preparations (0.4 %) and Kingbo (0.4 %) at the appropriate time. All treatments were watered with 25 mm of water (Filipovic and Kljajic, 2015).

Each year, several harvests were performed, whose results are shown in the form of combined values of all measurements, particularly: plant height (H), whole plant mass (MWP), number of flowers per plant (NFP), average flower mass (AMF), mass of flowers per plant (MFP), flower diameter (DF), yield of fresh flowers per hectare (FY) and yield of dry flowers per hectare (DY). Plant material was dried naturally, in a thin layer, in a protected, draughty place.

2.4. Laboratory analyses

2.4.1. Determining the contents of total carotenoids (TC)

The content of total carotenoids was determined by the application of the spectrotrometethric method. Samples of fresh pot marigold flower head were first homogenized and then 1 g was extracted with 50 mL of methanol, solvent best used for the extraction of carotenoids (Dere et al., 1998). Total carotenoids were calculated and expressed as μg/g of the sample. Analyzes were performed in three replications and the results were expressed as a mean ± standard deviation.

2.4.2. Determining the content of total phenols (TP)

The content of total phenols was determined by the spectrophotometric method according to Folin-Ciocâlteu using the same-name reagent (Singleton and Rossi, 1965). First, a certain sample volume is put into a 10 mL measuring container and then 2.5 mL of deionized water, 0.25 mL of Folin-Ciocâlteu solution, and 1 mL of sodium carbonate solution (20 %) were added. The container was then filled with water to the division line, and after 30 min, the absorbance is measured at the 760 nm wavelength, in relation to the water, as a blind trial. Gallic acid (0–100 mg/l) is used to create a calibration curve. Results are expressed as μg of gallic acid equivalents (GAE) per g of fresh flower or per mL of sample. Analyzes were performed in three replications and the results were expressed as a mean ± standard deviation.

2.4.3. Determining the contents of total flavonoids (TF)

The contents of the total flavonoids were determined by the spectrophotometric method with aluminum(III)-chloride (Chang et al., 2002). First, 0.5 mL of methanol extract was added to 0.1 mL of 10 % aluminum chloride followed by the addition of 0.1 mL of 1 M potassium acetate and 2.8 mL of distilled water. Then, the mixture was incubated at room temperature for 30 min, and absorbance was read at 415 nm wavelength. The standard curve was plotted based on different concentrations of quercetin, and the flavonoid value was determined to be equivalent to the amount of quercetin per gram of powdered plant (mg QUE/g). Analyzes were performed in three replications and the results were expressed as mean ± standard deviation.

2.4.4. Determination of antioxidant activity (DPPH)

Determining potential antioxidant activity using the DPPH assay was performed by spectrophotometric method. The antioxidant activity of the prepared flower pot marigold extracts was determined by using stable 2,2-diphenyl-1-picrylhydrazyl phosphate (DPPH) radical. The prepared extract (400 μl) was replenished to 2.0 mL with 0.1 mM of DPPH methanol solution, and absorption was measured after 30 min at 517 nm wavelength. DPPH reduction was calculated taking into account the absorption of the control trial, and the observed activity was compared with quercetin calibration curve. The results were expressed as quercetin antioxidant activity equivalent (QE) μmol per 100 mL of the solution (extract) (Bernatoniene et al., 2011). Analyzes were performed in three replications and the results were expressed as mean ± standard deviation.

2.5. Statistical analysis of data

2.5.1. ANN modeling

In this study, a multi-layer perceptron model (MLP), with three connected layers (input, hidden and output) was employed for model establishment. This model is commonly applied for approximating nonlinear functions (Hu and Weng, 2009; Karlović et al., 2013). Prior to computation, data were normalized to enhance the performance of the ANN model. Data was repeatedly presented to the network during model building sequence (Grieu et al., 2011; Pezo et al., 2013). The Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm was employed as an iterative procedure for solving unconstrained nonlinear problems in ANN modeling.

The database for ANN modeling was separated randomly, into training, cross-validation, and testing data (60 %, 20 % and 20 %, accordingly). The successful training of the ANN was reached when learning and cross-validation curves attained zero.

Coefficients involved with the hidden and output layer (weights and biases) are aggregated in matrices W_1 and B_1, and W_2 and B_2, while f_1 and f_2 are transfer functions in the hidden and output layers, accordingly. Vector X presents the input variables (Kollo and von Rosen, 2006; Trelea et al., 1997):

$$Y = f_1(W_2 \cdot f_2(W_1 \cdot X + B_1) + B_2) \tag{1}$$

The weight coefficients (elements of matrices W_1 and B_1, and W_2 and B_2) were calculated throughout the learning cycle, by updating them using BFGS to reduce the ANN estimation fault (Kollo and von Rosen, 2006; Trelea et al., 1997; Basheer and Hajmeer, 2000), according to the sum of squares (*SOS*) and BFGS algorithm, used to speed up and stabilize convergence (Basheer and Hajmeer, 2000). The coefficients of determination were exploited as parameters to inspect the efficiency of the acquired ANN model.

2.5.2. Statistical analysis

The statistical differences in means between different samples were explored according to Multivariate analysis of variance (MANOVA). Pattern recognition techniques, such as Principal Component Analysis (PCA) was utilized to access the experimental data (descriptors) and to portray and distinguish among the ascertained samples. All analyzes were done using the software package STATISTICA 10.0 (StatSoft Inc., Tulsa, OK, USA) (STATISTICA (Data Analysis Software System), v.10.0, 2010).

2.5.3. The accuracy of the models

The numerical confirmation of the ANN model was evaluated by coefficient of determination (R^2), reduced chi-square (χ^2), mean bias error (MBE), root mean square error (RMSE) and mean percentage error (MPE) (Arsenović et al., 2015):

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(x_{\exp,i} - x_{pre,i}\right)^2}{N-n}, \quad (2)$$

$$RMSE = \left[\frac{1}{N}\cdot\sum_{i=1}^{N}\left(x_{\exp,i} - x_{pre,i}\right)^2\right]^{1/2}, \quad (3)$$

$$MBE = \frac{1}{N}\cdot\sum_{i=1}^{N}\left(x_{\exp,i} - x_{pre,i}\right), \quad (4)$$

$$MPE = \frac{100}{N}\cdot\sum_{i=1}^{N}\left(\frac{\left|x_{\exp,i} - x_{pre,i}\right|}{x_{\exp,i}}\right), \quad (5)$$

where $x_{exp,i}$ is the experimental value and $x_{pre,i}$ is the ANN calculated value, N and n are the number of observations and the number of constants, respectively.

3. Results and discussion

3.1. Morphological and productive parameters of pot marigold

The impact of the application of certain amounts of compost derived from the waste from the production and processing of medicinal plants on the morphological and productive properties of pot marigold flower is shown in Tables 1 and 2.

Since there is no prior research on this topic, a comparison with literature data is not possible here. One of the examples of compost use is

Table 1
Statistical indicators of morphological and productive parameters of pot marigold, resulting from the application of different compost amounts produced from medicinal plant waste.

Year	Variety	Treatment	H (cm)	MWP (g)	NFP	AMF (g)
2013	DO	Control	50.775 ± 1.836^{de}	157.800 ± 6.256^{a}	$20.750 \pm 3.304^{abcdef}$	0.638 ± 0.051^{hijk}
2013	DO	2	54.700 ± 2.934^{efghi}	177.875 ± 2.604^{abc}	$26.500 \pm 5.802^{bcdefgh}$	0.730 ± 0.018^{ijkl}
2013	DO	10	$56.150 \pm 3.008^{fghijk}$	175.525 ± 3.721^{ab}	37.000 ± 9.626^{fghij}	0.733 ± 0.074^{ijkl}
2013	DO	30	56.575 ± 1.964^{ghijk}	179.475 ± 4.787^{abcd}	$24.500 \pm 8.583^{abcdefg}$	0.890 ± 0.145^{lmnop}
2013	PP	Control	41.675 ± 1.357^{c}	$187.475 \pm 1.737^{abcde}$	10.250 ± 0.957^{ab}	0.403 ± 0.043^{abcdef}
2013	PP	2	39.500 ± 1.949^{bc}	$192.425 \pm 1.977^{abcdef}$	12.500 ± 3.109^{abc}	$0.438 \pm 0.079^{abcdefg}$
2013	PP	10	37.000 ± 1.230^{abc}	$192.775 \pm 9.476^{abcdef}$	16.000 ± 4.243^{abcde}	0.493 ± 0.084^{cdefgh}
2013	PP	30	38.625 ± 2.470^{abc}	$195.400 \pm 3.061^{abcdefg}$	18.750 ± 3.304^{abcde}	$0.423 \pm 0.044^{abcdefg}$
2014	DO	Control	49.375 ± 0.613^{d}	367.650 ± 6.165^{mnop}	10.500 ± 2.082^{ab}	$0.435 \pm 0.068^{abcdefg}$
2014	DO	2	52.475 ± 0.585^{defgh}	359.675 ± 9.245^{mno}	13.000 ± 1.826^{abcd}	$0.460 \pm 0.067^{bcdefgh}$
2014	DO	10	$53.475 \pm 1.124^{defghi}$	$388.950 \pm 18.473^{mnopq}$	11.750 ± 2.217^{abc}	0.480 ± 0.061^{cdefgh}
2014	DO	30	55.325 ± 1.750^{efghi}	343.300 ± 17.140^{klm}	13.250 ± 1.500^{abcd}	0.510 ± 0.039^{cdefgh}
2014	PP	Control	48.925 ± 0.830^{d}	302.300 ± 23.293^{jkl}	7.000 ± 1.414^{a}	0.270 ± 0.029^{a}
2014	PP	2	52.500 ± 0.627^{defgh}	416.525 ± 26.940^{pqr}	7.500 ± 0.577^{a}	0.288 ± 0.032^{ab}
2014	PP	10	52.675 ± 0.780^{defgh}	$387.325 \pm 14.615^{mnopq}$	7.750 ± 1.258^{a}	0.345 ± 0.029^{abcd}
2014	PP	30	51.475 ± 0.645^{def}	422.025 ± 9.622^{qr}	8.750 ± 1.258^{a}	0.340 ± 0.038^{abc}
2015	DO	Control	37.525 ± 3.956^{abc}	290.000 ± 11.220^{ijk}	$29.000 \pm 10.708^{cdefghi}$	0.810 ± 0.066^{klmno}
2015	DO	2	52.525 ± 2.011^{defgh}	$366.025 \pm 29.219^{mnop}$	39.250 ± 10.340^{ghij}	0.895 ± 0.047^{lmnopq}
2015	DO	10	54.450 ± 1.827^{efghi}	$381.925 \pm 29.446^{mnopq}$	44.250 ± 16.661^{ij}	1.008 ± 0.095^{pq}
2015	DO	30	$56.100 \pm 1.356^{fghijk}$	341.425 ± 31.144^{klm}	44.750 ± 4.349^{ij}	0.923 ± 0.140^{nopq}
2015	PP	Control	50.950 ± 4.307^{de}	272.250 ± 25.319^{hij}	16.250 ± 2.217^{abcde}	0.403 ± 0.036^{abcdef}
2015	PP	2	61.100 ± 2.058^{k}	$230.475 \pm 46.224^{cdefgh}$	15.500 ± 2.380^{abcde}	0.403 ± 0.043^{abcdef}
2015	PP	10	57.175 ± 3.753^{hijk}	$200.375 \pm 22.562^{abcdefg}$	13.250 ± 1.500^{abcd}	0.503 ± 0.022^{cdefgh}
2015	PP	30	$55.550 \pm 1.905^{efghij}$	$232.400 \pm 16.275^{defgh}$	14.000 ± 3.162^{abcd}	$0.460 \pm 0.044^{bcdefgh}$
2016	DO	Control	48.950 ± 0.351^{d}	346.325 ± 16.881^{lmn}	38.250 ± 9.069^{fghij}	0.893 ± 0.054^{lmnop}
2016	DO	2	51.925 ± 0.585^{defg}	$398.250 \pm 10.121^{nopqr}$	52.750 ± 8.732^{j}	0.918 ± 0.038^{mnopq}
2016	DO	10	54.625 ± 0.858^{efghi}	$408.525 \pm 34.773^{opqr}$	43.000 ± 15.341^{hij}	0.835 ± 0.062^{lmnop}
2016	DO	30	57.150 ± 0.480^{hijk}	$388.250 \pm 21.437^{mnopq}$	50.000 ± 14.583^{j}	1.075 ± 0.070^{q}
2016	PP	Control	$53.750 \pm 0.532^{defghi}$	$407.550 \pm 11.154^{opqr}$	14.750 ± 3.304^{abcde}	0.473 ± 0.063^{cdefgh}
2016	PP	2	55.050 ± 0.311^{efghi}	435.100 ± 22.229^{qr}	16.500 ± 3.697^{abcde}	0.543 ± 0.058^{efgh}
2016	PP	10	58.025 ± 1.786^{ijk}	446.700 ± 17.340^{r}	14.250 ± 2.217^{abcd}	0.570 ± 0.037^{fghi}
2016	PP	30	60.475 ± 0.741^{jk}	431.400 ± 21.047^{qr}	16.750 ± 2.754^{abcde}	0.595 ± 0.054^{ghij}
2017	DO	Control	36.500 ± 1.407^{ab}	$181.875 \pm 21.563^{abcd}$	$21.250 \pm 3.403^{abcdef}$	0.738 ± 0.085^{ijklm}
2017	DO	2	39.725 ± 0.538^{bc}	$201.400 \pm 15.278^{abcdefg}$	$30.250 \pm 4.992^{defghi}$	0.760 ± 0.032^{jklmn}
2017	DO	10	37.700 ± 0.716^{abc}	$248.050 \pm 18.307^{ghij}$	40.000 ± 8.287^{ghij}	0.785 ± 0.055^{klmno}
2017	DO	30	38.900 ± 0.408^{abc}	$239.875 \pm 26.872^{efghi}$	32.000 ± 4.690^{efghi}	0.948 ± 0.109^{opq}
2017	PP	Control	37.175 ± 0.776^{abc}	$228.825 \pm 20.714^{bcdefgh}$	12.250 ± 1.708^{abc}	0.383 ± 0.038^{abcde}
2017	PP	2	36.500 ± 1.949^{ab}	$201.800 \pm 11.418^{abcdefg}$	13.000 ± 4.082^{abcd}	0.403 ± 0.036^{abcdef}
2017	PP	10	$34.000 \pm 1.\ 230^{a}$	$232.800 \pm 15.519^{defgh}$	14.750 ± 2.630^{abcde}	0.523 ± 0.087^{defgh}
2017	PP	30	35.625 ± 2.470^{ab}	$242.900 \pm 12.140^{fghi}$	16.000 ± 1.414^{abcde}	0.493 ± 0.021^{cdefgh}

H – Plant height; MWP – Mass of the whole plant; NFP – Number of flowers on plant; AMF – The average mass of the flower; DO – *Domaći oranž*; PP – *Plamen Plus*.

Table 2
Statistical indicators of morphological and productive properties of pot marigold resulting from the application of different compost amounts produced from medicinal plant waste.

Year	Variety	Treatment	MFP g	DF mm	FY kg/ha	DY kg/ha
2013	DO	Control	13.133 ± 1.444^{abcdef}	4.975 ± 0.532^{cdefghi}	4377.325 ± 481.347^{abcdef}	841.793 ± 92.567^{abcdef}
2013	DO	2	19.283 ± 3.802^{bcdefgh}	5.450 ± 1.226^{defghi}	6427.243 ± 1267.225^{bcdefgh}	1236.008 ± 243.697^{bcdefgh}
2013	DO	10	27.523 ± 9.674^{fghij}	6.575 ± 1.717^{fghijk}	9173.800 ± 3224.478^{fghij}	1764.192 ± 620.092^{fghij}
2013	DO	30	21.620 ± 8.105^{cdefghi}	6.375 ± 2.148^{fghijk}	7206.378 ± 2701.687^{cdefghi}	1388.919 ± 515.950^{cdefghi}
2013	PP	Control	4.105 ± 0.354^{ab}	8.375 ± 0.585^{jklmn}	1368.279 ± 117.894^{ab}	276.336 ± 25.218^{ab}
2013	PP	2	5.435 ± 1.559^{ab}	9.350 ± 0.881^{lmn}	1811.594 ± 519.755^{ab}	348.384 ± 99.953^{ab}
2013	PP	10	7.798 ± 1.997^{abcd}	9.600 ± 0.845^{mn}	2599.063 ± 665.675^{abcd}	503.854 ± 130.037^{abcd}
2013	PP	30	7.915 ± 1.606^{abcd}	9.700 ± 1.643 ^{n}	2638.228 ± 535.339^{abcd}	507.352 ± 102.950^{abcd}
2014	DO	Control	4.668 ± 1.641^{ab}	3.075 ± 0.310^{abcd}	1555.771 ± 546.884^{ab}	299.187 ± 105.170^{ab}
2014	DO	2	6.008 ± 1.312^{ab}	2.450 ± 0.342^{ab}	2002.420 ± 437.462^{ab}	385.081 ± 84.127^{ab}
2014	DO	10	5.703 ± 1.602^{ab}	1.975 ± 0.435^{a}	1900.757 ± 533.828^{ab}	365.530 ± 102.659^{ab}
2014	DO	30	6.718 ± 0.346^{abc}	2.675 ± 0.443^{abc}	2239.077 ± 115.285^{abc}	430.592 ± 22.170^{abc}
2014	PP	Control	1.868 ± 0.288^{a}	5.125 ± 1.520^{cdefghi}	622.475 ± 95.966^{a}	119.707 ± 18.455^{a}
2014	PP	2	2.158 ± 0.307^{a}	5.325 ± 0.842^{defghi}	719.138 ± 102.208^{a}	138.296 ± 19.655^{a}
2014	PP	10	2.680 ± 0.555^{a}	4.000 ± 1.160^{abcdef}	893.298 ± 185.145^{a}	171.788 ± 35.605^{a}
2014	PP	30	2.968 ± 0.519^{a}	4.800 ± 1.175^{bcdefgh}	989.127 ± 172.864^{a}	190.217 ± 33.243^{a}
2015	DO	Control	23.675 ± 9.774^{efghi}	3.700 ± 0.183^{abcde}	7891.351 ± 3257.861^{efghi}	1517.568 ± 626.512^{efghi}
2015	DO	2	35.485 ± 11.260^{ijkl}	3.800 ± 0.216^{abcde}	11,827.860 ± 3753.285^{ijkl}	2274.589 ± 721.786^{ijkl}
2015	DO	10	43.635 ± 13.756^{klm}	6.650 ± 0.465^{ghijk}	14,544.418 ± 4585.024^{klm}	2797.004 ± 881.735^{klm}
2015	DO	30	40.985 ± 4.503^{jklm}	6.475 ± 0.608^{ghijk}	13,661.120 ± 1501.101^{jklm}	2627.139 ± 288.673^{jklm}
2015	PP	Control	6.500 ± 0.633^{abc}	5.925 ± 0.499^{efghij}	2166.580 ± 211.038^{abc}	416.650 ± 40.584^{abc}
2015	PP	2	6.185 ± 0.620^{ab}	8.500 ± 0.668^{klmn}	2061.584 ± 206.739^{ab}	396.459 ± 39.758^{ab}
2015	PP	10	6.658 ± 0.800^{abc}	9.475 ± 1.588^{lmn}	2219.078 ± 266.661^{abc}	426.746 ± 51.281^{abc}
2015	PP	30	6.438 ± 1.653^{abc}	9.675 ± 0.750^{mn}	2145.748 ± 550.912^{abc}	412.644 ± 105.945^{abc}
2016	DO	Control	33.880 ± 6.854^{hijkl}	7.400 ± 0.316^{ijklmn}	11,292.882 ± 2284.555^{hijkl}	2171.708 ± 439.337^{hijkl}
2016	DO	2	48.360 ± 8.225 ^{lm}	7.225 ± 0.171^{hijklm}	16,119.355 ± 2741.519 ^{lm}	3099.876 ± 527.215 ^{lm}
2016	DO	10	35.590 ± 12.227^{ijkl}	7.125 ± 0.532^{hijkl}	11,862.859 ± 4075.570^{ijkl}	2281.319 ± 783.763^{ijkl}
2016	DO	30	53.180 ± 13.058 ^{m}	7.275 ± 0.359^{ijklmn}	17,725.958 ± 4352.381 ^{m}	3408.838 ± 836.996 ^{m}
2016	PP	Control	6.980 ± 1.929^{abc}	8.075 ± 0.602^{jklmn}	2326.574 ± 643.017^{abc}	447.418 ± 123.657^{abc}
2016	PP	2	8.793 ± 1.089^{abcde}	8.700 ± 0.804^{klmn}	2930.716 ± 362.971^{abcde}	563.599 ± 69.802^{abcde}
2016	PP	10	8.138 ± 1.543^{abcd}	8.600 ± 0.883^{klmn}	2712.392 ± 514.166^{abcd}	521.614 ± 98.878^{abcd}
2016	PP	30	9.995 ± 2.087^{abcde}	9.600 ± 0.707^{mn}	3331.533 ± 695.617^{abcde}	640.680 ± 133.773^{abcde}
2017	DO	Control	15.610 ± 2.545^{abcdefg}	3.630 ± 0.273^{abcde}	5203.125 ± 848.154^{abcdefg}	1000.601 ± 163.106^{abcdefg}
2017	DO	2	22.968 ± 3.831^{defghi}	4.550 ± 0.265^{bcdefg}	7655.527 ± 1276.865^{defghi}	1472.217 ± 245.551^{defghi}
2017	DO	10	31.540 ± 7.588^{hijk}	4.450 ± 0.443^{bcdefg}	10,512.913 ± 2529.356^{hijk}	2021.714 ± 486.415^{hijk}
2017	DO	30	30.133 ± 4.174^{ghijk}	4.200 ± 0.271^{abcdefg}	10,043.765 ± 1391.350^{ghijk}	1931.493 ± 267.567^{ghijk}
2017	PP	Control	4.703 ± 0.870^{ab}	6.500 ± 0.622^{ghijk}	1567.437 ± 289.872^{ab}	301.430 ± 55.745^{ab}
2017	PP	2	5.178 ± 1.484^{ab}	7.353 ± 0.405^{ijklmn}	1725.764 ± 494.741^{ab}	331.878 ± 95.142^{ab}
2017	PP	10	7.763 ± 2.224^{abcd}	8.050 ± 0.592^{jklmn}	2587.397 ± 741.252^{abcd}	497.576 ± 142.549^{abcd}
2017	PP	30	7.873 ± 0.678^{abcd}	8.125 ± 1.081^{jklmn}	2624.062 ± 226.026^{abcd}	504.627 ± 43.466^{abcd}

MFP – Mass of flowers per plant; DF – Flower diameter; FY – Flower fresh yield; DY – Flower dry yield; DO – *Domaći oranž*; PP – *Plamen Plus*.

the application of swine manure as a fertilizer for pot marigold. Pot marigold had the largest vegetative increase and a larger number of flowers in those treatments where only 40 % of commercial substrate was replaced with swine manure (Atiyeh et al., 2002). In the case of morphological parameters, the MANOVA test showed significantly different values for the full cross between effects of the year × variety × treatment (Wilk's lambda = 0.077, F = 2.549; $p \leq 0.001$). Significant differences were detected in the following parameters: H (F = 83.742, $p \leq 0.01$), MWP (F = 0.969, p < 0.01), NFP (F = 0.847, $p \leq 0.01$), AMF (F = 48.377, $p \leq 0.01$), shown in Table 1. Depending on the amount of compost applied, the variety and the year, the average plant height (H) varies between 36.8 and 58.8 cm. The treatment with the highest value was with 30 kg/m^2 of compost, and the lowest was control treatment. Whole plant mass (MWP) shows that the mineral plant nutrition with 10 kg/m^2 of compost yielded the best results in both varieties (Table 1).

The number of flowers per plant (NFP) was highest in the *Domaći oranž* variety the treatment with 10 kg/m^2 of compost (35.2), which was 2.36 times higher compared with the highest NFP in the *Plamen Plus* variety (14.9 in the treatment with 30 kg/m^2 of compost).

By applying vermicompost, Sardoei (2014) obtained NFP values in the interval as the one obtained in this research. Similar results were achieved by Crnobarac et al. (2008), whereas a certain number of authors obtained NFP more than 50 flowers per plant (Król, 2011a, 2012), and some obtained more than 70, even up to 140 (Khalid et al., 2006). There are several possible reasons for such a large difference in the NFP, namely differences in genotype, soil type, conditions of the environment and various agrotechnical measures (Zarrinabadi et al., 2019). The average mass of flower (AMF) in variety *Domaći oranž* was 0.70 (control treatment) to 0.87 g per flower (treatment with 30 kg/m^2 compost), in variety *Plamen Plus*, AMF was half as much and ranged from 0.39 (control treatment) to 0.49 g per flower (treatment with 10 kg/m^2 compost).

In the case of morphological parameters, the MANOVA test showed significantly different values for the full cross between effects of the year × variety × treatment. Significant differences were detected in the following parameters: MFP (F = 28.355, $p \leq 0.01$), DF (F = 27.270, $p \leq 0.01$), FY (F = 28.355, $p \leq 0.01$), and DY (F = 28.355, $p \leq 0.01$), shown in Table 2. The mass of flowers per plant (MFP) depended largely on the NFP and AMF (Table 2). The largest MFP for both varieties tested were in treatments with the highest applied amount of compost. The larger bloom, i.e., larger diameter, had the *Plamen Plus* variety in all treatments of compost waste and in all years of testing. Similar results, i.e., significantly higher blooms than the flowery varieties tested, were obtained in experiments at the Faculty of Agriculture in Novi Sad (Serbia), compared with the Czech varieties *Plamen Plus* (5.1 cm) and *Plamen* (4.7 cm) (Jaćimović et al., 2010). Drought stress (Fig. 1.) significantly reduces the values of many morphological and productive parameters (plant height, flower diameter, dry weight of shoots, fresh, dry weight of flowers, etc.) in pot marigold based on reports of

Abdul-Wasea and Khalid (2010) and Shokrani et al. (2012). The proper selection of the variety is certainly one of perhaps the most important items in the entire agrotechnics of pot marigold cultivation. Variety *Domaći oranž* is the most used variety in Serbia and it is well adapted to local agroecological conditions yielding 400–700 kg/ha of petals or about 1000–2000 kg/ha of dried blossom heads/flowers.

The achieved yields of the *Domaći oranž* variety in this study correspond to these values. Specifically, the best yields of fresh flower (FY) and dry flower (DY) had treatments with 10 kg/m^2 compost (9598.9 kg/ha and 1846.0 kg/ha, respectively) or 30 kg/m^2 compost (10,175.3 kg/ha and 1957.4 kg/ha, respectively). Fertilization with 40 t/ha of manure in agroecological conditions of Cluj, Napoca (Romania), achieved the yield of a fresh flower from 8900 to 10,200 kg/ha depending on the variety (Muntean et al., 2009). Similar results were obtained in this research with *Domaći oranž* variety, where the control treatment averaged about 3837 kg/ha of flower yield of fresh flower compared with the other compost treatments which averaged from 5328 kg/ha (2 kg/m^2 compost) to 6260 kg/ha (30 kg/m^2 compost). In experiments from Cluj, by reducing the amount of manure to 20 t/ha, the yield of fresh flower pot marigold was reduced by about 1000 kg/ha (Muntean et al., 2013). In two years of research in the Tehran area (Iran) in the treatment of different types of biostimulators (amino acids and certain NPK nutrients) the yield of dry flower was achieved in range of 267–440 kg/ha (Rafiee et al., 2015). Dry flower yields of 1000–2000 kg/ha in various research were recorded by several researchers (Gomes et al., 2007; Mrđa et al., 2007; Król, 2011a, 2012). A higher yield of 4000 kg/ha of dry flower yield was achieved in research in Chile (Berti et al., 2003).

3.2. Qualitative parameters of pot marigold flower

The effects of the application of certain amounts of compost obtained from the waste from medicinal plant production and processing on the qualitative parameters of pot marigold flower is shown in Table 3.

In case of morphological parameters, MANOVA test showed significantly different values for the full cross between effects year × variety × treatment. Significant differences were detected in parameters: TC (F = 27.081, $p \leq 0.01$), TP (F = 10.372, $p \leq 0.01$), TF (F = 31.073, $p \leq 0.01$), and DPPH (F = 6.797, $p \leq 0.01$), shown in Table 3.

The content of TC depends on many factors (variety, locality, agroecological conditions and others). In studies by Pintea et al. (2003), TC content in fresh marigold flowers depended on variety and differed over 228 mg/100 g. A 12–15 times higher content of TC was in dried flowers compared with the fresh one (Bako et al., 2002; Raal et al., 2009). The highest content of TC (mg/g in dry weight) was recorded in marigold flower petals (7.71 %), whereas it was far lower in pollen (1.61 %), as well as in leaves (0.85 %), while it was the smallest in the stem (0.18 %) (Goodwin, 1954). In this study, a higher content of TC was recorded in the *Plamen Plus* variety (3.2 μg/g), while it was lower by about 15.6 % (2.7 μg/g) in the *Domaći oranž*. The content of TC increased from control treatment to treatment with maximum amount of applied compost of

Table 3
Statistical indicators of qualitative parameters of pot marigold, resulting from the application of different amounts of compost produced from medicinal plant waste.

Year	Variety	Treatment	TC μ/g	TP mg GAE/g	TF mg QUE/g	DPPH QE μmol/100 mL
2013	DO	Control	2.090 ± 0.352^{abcdef}	22.330 ± 9.355^{ab}	22.338 ± 4.458^{ghi}	$96.300 \pm 24.713^{bcdefghi}$
2013	DO	2	$2.300 \pm 0.327^{abcdefgh}$	$35.830 \pm 17.567^{abcdefghi}$	20.775 ± 3.621^{fgh}	$87.470 \pm 19.953^{abcdefgh}$
2013	DO	10	$2.113 \pm 0.169^{abcdefg}$	23.985 ± 8.715^{abcd}	24.990 ± 5.589^{ghijk}	69.090 ± 14.009^{abc}
2013	DO	30	2.968 ± 0.257^{efghi}	25.410 ± 7.534^{abcde}	23.177 ± 3.000^{ghij}	62.383 ± 11.300^{a}
2013	PP	Control	$2.280 \pm 0.319^{abcdefgh}$	$26.813 \pm 10.265^{abcdef}$	31.603 ± 3.111^{ijklm}	$97.935 \pm 10.384^{bcdefghi}$
2013	PP	2	$2.635 \pm 0.237^{bcdefgh}$	$33.050 \pm 9.559^{abcdef}$	38.735 ± 4.629^{mn}	112.545 ± 1.588^{ghi}
2013	PP	10	$2.620 \pm 0.433^{bcdefgh}$	$29.090 \pm 10.837^{abcdef}$	34.818 ± 2.878^{klmn}	110.393 ± 1.845^{ghi}
2013	PP	30	3.335 ± 0.429^{fghij}	$37.593 \pm 14.058^{abcdefghij}$	35.270 ± 4.355^{klmn}	$93.480 \pm 1.420^{abcdefghi}$
2014	DO	Control	1.443 ± 0.237^{abcd}	$30.800 \pm 10.783^{abcdef}$	9.205 ± 3.278^{abcd}	68.880 ± 2.246^{ab}
2014	DO	2	$2.160 \pm 0.914^{abcdefg}$	23.423 ± 13.590^{abc}	8.248 ± 1.949^{abcd}	$104.105 \pm 18.174^{defghi}$
2014	DO	10	1.980 ± 0.511^{abcdef}	20.590 ± 6.698^{ab}	6.818 ± 1.226^{ab}	$102.893 \pm 6.945^{defghi}$
2014	DO	30	2.030 ± 0.643^{abcdef}	$29.698 \pm 12.453^{abcdef}$	7.620 ± 1.832^{abc}	$100.685 \pm 15.820^{cdefghi}$
2014	PP	Control	1.258 ± 0.160^{abc}	$30.878 \pm 9.992^{abcdef}$	$11.515 \pm 1.882^{abcdef}$	$77.088 \pm 5.073^{abcdef}$
2014	PP	2	1.573 ± 0.367^{abcde}	$32.728 \pm 11.904^{abcdef}$	10.098 ± 2.527^{abcde}	75.320 ± 2.773^{abcde}
2014	PP	10	$2.448 \pm 0.498^{abcdefgh}$	$37.410 \pm 8.043^{abcdefghij}$	$11.418 \pm 1.776^{abcdef}$	68.940 ± 1.169^{ab}
2014	PP	30	2.738 ± 0.782^{cdefgh}	60.388 ± 6.392^{jk}	8.290 ± 1.654^{abcd}	$81.320 \pm 10.104^{abcdefg}$
2015	DO	Control	3.130 ± 0.415^{fghij}	$32.568 \pm 3.082^{abcdef}$	17.663 ± 3.522^{cdefg}	$91.808 \pm 4.041^{abcdefghi}$
2015	DO	2	3.388 ± 0.277^{fghij}	$34.298 \pm 4.645^{abcdefg}$	$16.428 \pm 2.862^{abcdefg}$	$81.948 \pm 7.883^{abcdefg}$
2015	DO	10	4.238 ± 0.626^{ijkl}	$30.748 \pm 4.640^{abcdef}$	19.758 ± 4.415^{efgh}	72.600 ± 7.241^{abcd}
2015	DO	30	6.105 ± 0.959^{n}	$28.388 \pm 2.225^{abcdef}$	18.325 ± 2.372^{defgh}	$76.605 \pm 8.128^{abcdef}$
2015	PP	Control	3.608 ± 0.818^{ghij}	$27.480 \pm 6.717^{abcdef}$	24.458 ± 4.188^{ghij}	$84.878 \pm 7.394^{abcdefgh}$
2015	PP	2	3.715 ± 0.734^{hijk}	$46.230 \pm 6.505^{cdefghijk}$	$26.130 \pm 4.591^{ghijkl}$	110.263 ± 12.267^{ghi}
2015	PP	10	5.135 ± 0.737^{klmn}	$48.208 \pm 4.001^{efghijk}$	28.388 ± 7.280^{hijkl}	$105.750 \pm 15.857^{efghi}$
2015	PP	30	6.528 ± 0.778^{n}	$46.755 \pm 11.244^{cdefghijk}$	22.470 ± 4.888^{ghi}	$90.378 \pm 10.918^{abcdefghi}$
2016	DO	Control	1.118 ± 0.186^{a}	19.408 ± 4.794^{ab}	8.193 ± 1.426^{abcd}	$97.460 \pm 11.875^{bcdefghi}$
2016	DO	2	1.145 ± 0.168^{ab}	15.475 ± 3.998^{a}	6.520 ± 0.956^{ab}	$88.510 \pm 7.389^{abcdefgh}$
2016	DO	10	1.578 ± 0.133^{abcde}	16.073 ± 2.938^{a}	7.353 ± 1.729^{ab}	$77.555 \pm 11.273^{abcdef}$
2016	DO	30	1.370 ± 0.088^{abc}	21.190 ± 2.198^{ab}	6.260 ± 0.674^{a}	111.055 ± 23.521^{ghi}
2016	PP	Control	1.470 ± 0.453^{abcd}	$35.363 \pm 2.342^{abcdefghi}$	$16.560 \pm 0.965^{bcdefg}$	$94.075 \pm 10.281^{abcdefghi}$
2016	PP	2	$2.308 \pm 0.694^{abcdefgh}$	$41.668 \pm 9.317^{bcdefghijk}$	22.713 ± 3.084^{ghi}	$95.820 \pm 12.294^{bcdefghi}$
2016	PP	10	$2.405 \pm 0.190^{abcdefgh}$	$34.808 \pm 1.815^{abcdefgh}$	21.585 ± 3.212^{fghi}	$92.890 \pm 10.957^{abcdefghi}$
2016	PP	30	2.998 ± 0.276^{efghi}	$28.618 \pm 4.289^{abcdef}$	19.665 ± 4.249^{efgh}	$84.373 \pm 26.086^{abcdefg}$
2017	DO	Control	2.913 ± 0.407^{defghi}	$28.738 \pm 11.199^{abcdef}$	$26.520 \pm 3.988^{ghijkl}$	$90.120 \pm 3.624^{abcdefghi}$
2017	DO	2	3.023 ± 0.323^{efghi}	$49.190 \pm 3.438^{fghijk}$	25.088 ± 3.959^{ghijk}	$86.390 \pm 3.507^{abcdefgh}$
2017	DO	10	3.753 ± 0.383^{hijk}	64.765 ± 7.092^{k}	23.268 ± 5.677^{ghij}	$80.843 \pm 3.505^{abcdefg}$
2017	DO	30	5.353 ± 0.939^{lmn}	64.093 ± 7.664^{k}	19.528 ± 3.529^{efgh}	$88.005 \pm 6.623^{abcdefgh}$
2017	PP	Control	2.868 ± 0.627^{defghi}	$47.125 \pm 7.202^{defghijk}$	33.293 ± 3.455^{jklmn}	107.378 ± 1.352^{fghi}
2017	PP	2	3.130 ± 0.399^{fghij}	57.610 ± 8.732^{ghijk}	35.973 ± 6.271^{lmn}	110.855 ± 6.144^{ghi}
2017	PP	10	4.563 ± 0.517^{jklm}	57.908 ± 4.071^{hijk}	42.033 ± 3.531^{n}	116.285 ± 2.440^{i}
2017	PP	30	5.760 ± 0.894^{mn}	58.630 ± 7.482^{ijk}	35.258 ± 3.823^{klmn}	120.303 ± 3.807^{i}

TC – Total carotenoids; TP – Total phenolic; TF – Total flavonoids; DPPH – DPPH reduction; DO – *Domaći oranž*; PP – *Plamen Plus*.

30 kg/m^2, both in varieties and in all years. Compared with these results, higher TC contents were achieved in research conducted in Cluj, Napoca (Romania).

The carotenoids concentrations varied between 6,83 and 17,9 mg/100 g (1 mg/g = 1000 μg/g) vegetal product for the fresh samples and between 48,8 and 132,6 mg/100 g vegetal product for the dried samples (Muntean et al., 2009). According to previous studies, pot marigold accumulates large amounts of different carotenoids in its flowers. The yellow and orange color of petals is mostly due to the carotenoids and the shade depends on the quantity and composition of pigments (Sausserde and Kampuss, 2014). Variety *Plamen Plus* grown under field conditions in Slovakia and Bulgaria showed different carotenoid contents and antioxidant response to the specific soil and climatic conditions (Plackova et al., 2010). Different mineral nutrition changed the chemical composition of plants; the increase in nutrients leads to increased content of compounds (Kishimoto et al., 2005; Legha et al., 2012; Sausserde and Kampuss, 2014). In the case of less fertile soils, the length of flowering mainly depends on the amount of used mineral nutrients. According to the research of Olennikov and Kashchenko (2013), the highest TC content was in the *Flame Dancer* variety (7.59 mg/g), then the *Big Orange* variety (6.56 mg/g), while the lowest TC content was in *Indian Prince* variety (5.14 mg/g). Consistency of quality needs to be examined as Piccaglia et al. (1997) found that pigment levels in pot marigold flower heads varied considerably between years. Piccaglia et al. (1997) studied the agronomic parameters, flavonoid and carotenoid contents of an Italian pot marigold which were evaluated over a two-year trial performing two annual cuts during the flowering period. The number of flower heads per plant and the yield of heads and petals were found to be higher in the second cut, but the pigment content greatly differed in the second year. In this study, a higher content of TP was also recorded in the *Plamen Plus* (40.9 mg GAE/g), while the *Domaći oranž* had a lower value about 24.4 % on a five-year average, i.e., 30.8 mg GAE/g. Different levels of compost fertilization did not lead to major deviations of the measured values of total phenols content except in the control treatment. In the research of Ćetković et al. (2003), the TP content in marigold flowers was 15.12 mg GAE/g, while the total flavonoid content was 5.13 mg QE/g. Butnariu and Coradini (2012) determined the content of phenolic compounds in marigold extracts prepared with methanol (80 %), ethanol (96 % and 60 %), isopropanol (99 %) by spectrophotometric method. The highest content of polyphenolic compounds was determined in methanol extract and was 153 mg GAE/100 mL of extract. Therefore, organic fertilization with foliar fertilizer is recommended for growing pot marigold plants, that can give higher levels of phenolic compounds (Onofrei et al., 2017). Kaškonienė et al. (2011) analyzed the methanolic extracts of individual marigold hybrids and the content of polyphenolic compounds, flavonoids and antioxidant activity of the DPPH method was determined by spectrophotometric method. In this research, it has been confirmed that the content of polyphenolic compounds was 2.5 times higher in hybrid marigold species, and the antioxidant activity was as much as 25 times higher (Kaškonienė et al., 2011). In this study, the highest TF content for both examined varieties was in the treatment with 10 kg/m^2 compost. Overall, the *Plamen Plus* variety had a TF average of 25.5 mg QUE/g, while the *Domaći oranž* variety had a TF average of 15.9 mg QUE/g. In the experiment of Ocioszyńska et al. (1977), the percentage of flavonoids (expressed in quercetin) was in a range of 0.2–0.8 %, while Kurkin and Sharowa (2007) report values from 0.3 % up to 0.7 %. The TF content in dried marigold flowers, which was treated with different biostimulators depending on the year and ranged from 0.12 to 0.25 and 0.46 to 0.53 mg/g DW (Rafiee et al., 2015). In studies in Takestan (Iran), the maximum flavonoid content was obtained by applying 30 kg N/ha and irrigating with 80 mm of water (Rahmani et al., 2012). In studies in Moscow (Russia), the TF content of seven cultivated marigold cultivars ranged from 10.52 (*Flame Dancer* variety) to 26.79 mg/g (*Big Orange* variety) (Olennikov and Kashchenko, 2013). On the other hand, in studies conducted in Romania (Butnariu and Coradini, 2012), the average TF content of the two tested marigold varieties *Petran* and *Plamen* was 96.17 and 90.37 mg QE/100 mL, respectively. All of the above results suggest that differences in localities affect the TF content. Brighente et al. (2007) confirm that there is a direct correlation between TP content and antioxidant capacity of the medicinal plants. In this study, a higher content of DPPH was recorded in the *Plamen Plus* (96.5 QE μmol/100 mL), while in the *Domaći oranž* it was lower by about 10.1 % (86.7 QE μmol/100 mL). The content of the tested parameter was not significantly affected by the tested quantities of applied compost. For the methanol extract of pot marigold *Petran* and *Plamen* varieties, the DPPH radical scavenging activity was 2,64 and 2,97 mmol Trolox/g (Butnariu and Coradini, 2012). On the other hand, in cultivated pot marigold the DPPH dissolved in methanol extract at concentrations of 250, 500 and 1000 μg/mL, had values of 4.07, 7.34 and 11.77 QE μmol/100 mL (Ercetin et al., 2012).

3.3. PCA analysis

The PCA graph of the exhibited data shows that the first two components represented the 68.08 % of the total variance (44.84 % and 23.24 % accordingly) in the eleven variables system (morphological and productive properties and statistical indicators of qualitative properties resulting from the application of different compost data). Considering PCA analysis, MFP (which accounted for 17.0 % of total variance, based on correlations), FY (17.0 %), DY (17.0 %), NFP (16.3 %) and AMF (15.2 %) exhibited negative scores according to first principal component (PC1). The positive score according to the second principal component (PC2) was noticed for the TC (15.7 %), TF (20.2 %) and TP (9.2 %). The negative share to PC2 was noticed for: H (12.4 % of total variance) and MWP (15.4 %). According to PCA analysis, PC 1 coordinate describes the difference between pot marigold varieties, but also the differences in compost treatment. The higher DY, FY, MFP, NFP and AMF were observed for more intensive compost treatment, regardless the pot marigold variety or the year in which it was grown. The positive correlations (0.923–1.000, $p \leq 0.001$), between DY, FY, MFP, NFP and AMF could be visually realized on the PCA plot, according to almost identical direction of vectors. The second principal component (PC 2) describes the differences in environmental conditions in the specific years (caused by the air temperature and precipitations), but also in compost treatment for the pot marigold plants. The higher TC, DF, TF, TP and DPPH values are observed for the more intensive compost treatment, especially in 2017, when the precipitation conditions and the temperatures were low. The positive correlations (0.462–0,586, $p \leq 0.01$) between TC, DF, TF, TP and DPPH were obtained from the correlation analysis, while H and MWP values were the highest in 2014 and 2016, due to high precipitation conditions. The positive correlation (0.506, $p \leq 0.001$) between H and MWP was shown in the correlation analysis.

3.4. ANN model

The constructed optimal ANN model demonstrated the sufficient prediction potential for data, and might be employed to foresee the productivity and quality of pot marigold flowers which was based on the compost material, produced from waste of medicinal plants. In accordance with the obtained ANN operation, the optimal number of neurons in the hidden layer for H, MWP, NFP, AMF, MFP, DF, FY, DY, TC, TP, TF and DPPH calculation was 9 (network MLP 3-9-12) to obtain the high values of R^2 (0.837 for ANN throughout the training period) and low values of *SOS* (Table 4).

The goodness of fit among experimental and ANN computed values, depicted as ANN conduct (R^2 between experimental and ANN computed H, MWP, NFP, AMF, MFP, DF, FY, DY, TC, TP, TF and DPPH), during training, testing and validation cycles, are displayed in Table 5.

The developed ANN model anticipated experimental data (H, MWP, NFP, AMF, MFP, DF, FY, DY, TC, TP, TF and DPPH) fairly good for a wide

Table 4
Artificial neural network model summary (performance and errors), for training, testing and validation cycles.

Network name	Training perf.	Test perf.	Validation perf.	Training error	Test Error	Validation Error	Training Algorithm	Error function	Hidden activation	Output activation
MLP 3-9-12	0.837	0.584	0.484	0.006	0.027	0.040	BFGS 56	SOS	Tanh	Logistic

Performance term represent the coefficients of determination, while error terms indicate a lack of data for the ANN model.

Table 5
Coefficients of determination (R^2) between experimentally measured and ANN outputs, during training, testing and validation steps.

Cycle	H	MWP	NFP	AMF	MFP	DF	FY	Y	TC	TP	TF	DPPH
Train.	0.920	0.831	0.975	0.953	0.961	0.899	0.961	0.960	0.706	0.755	0.930	0.337
Test.	0.444	0.536	0.931	0.982	0.974	0.843	0.975	0.972	0.239	0.840	0.673	0.081
Valid.	0.802	0.399	0.609	0.956	0.815	0.723	0.818	0.809	0.100	0.155	0.325	0.051

H – Plant height; MWP – Mass of the whole plant; NFP – Number of flowers on plant; AMF – The average mass of the flower; MFP – Mass of flowers per plant; DF – Flower diameter; FY – Fresh flower yield; DY – Dry flower yield; TC – total carotenoids; TP – total phenolic; TF – total flavonoids; DPPH – DPPH reduction.

variety of the process variables. The forecasted values were very near to the measured values in most situations, in respect of R^2 values (Kollo and von Rosen, 2006; Montaño and Palmer, 2003), as presented in Fig. 2.

The gained ANN model is sophisticated (156 weights-biases) due to the high nonlinearity of the established system (Kollo and von Rosen, 2006; Montgomery, 2014). The R^2 values amidst experimental measurements and ANN model outputs, H, MWP, NFP, AMF, MFP, DF, FY, DY, TC, TP, TF and DPPH were: 0,780; 0,674; 0.929; 0.945; 0.952; 0.877; 0.952; 0.950; 0.535; 0.701; 0.842 and 0.235, respectively.

Table 6 offers the elements of matrix W_1 and vector B_1 (displayed in the bias column), and Table 7 portrays the elements of matrix W_2 and vector B_2 (bias) for the hidden layer, applied in Eq. (1).

Model fit was investigated and the residual analysis of the constructed ANN model is given in Table 8. The ANN model had a negligible error, which means that the ANN model properly predicted the experimental data. A high R^2 indicates that the variation is explained and that the data fitted the suggested model correctly (Chattopadhyay and Rangarajan, 2014; Montgomery, 1984; Montaño and Palmer, 2003).

Table 6
Elements of matrix W_1 and vector B_1 (presented in the bias column).

	Year	Variety	Treatment	Bias
1	0.255	7.942	-8.424	-0.586
2	0.281	0.367	6.329	-6.149
3	-5.124	0.059	-0.569	-1.184
4	7.032	0.911	4.927	-0.648
5	-0.881	0.223	-5.208	-1.061
6	0.199	0.813	0.033	-0.332
7	2.147	2.462	2.372	3.499
8	0.314	1.973	-1.979	-2.740
9	-0.474	-0.024	-0.327	-2.201

4. Conclusions

Based on the results of this study, it was found that the application of compost from waste of the production and processing of medicinal plants had a positive impact on the morphological and productive characteristics, and flower quality of two pot marigolds varieties. The use of compost in this way is in accordance with the circular economy

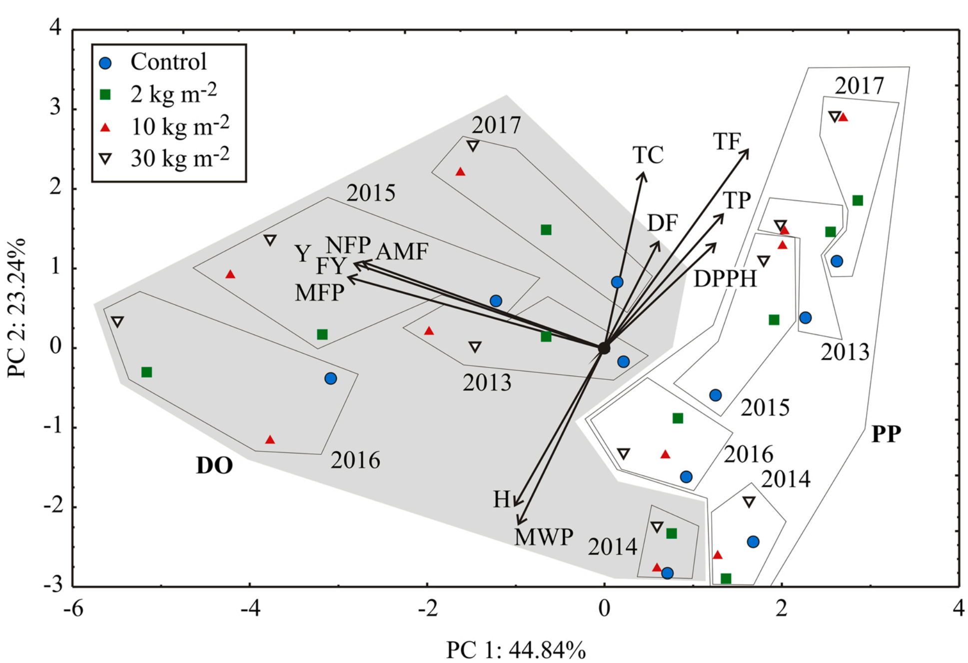

Fig. 2. PCA ordination of variables based on component correlations. H – Plant height; MWP – Mass of the whole plant; NFP – Number of flowers on plant; AMF – The average mass of the flower; MFP – Mass of flowers per plant; DF – Flower diameter; FY – Fresh flower yield; DY – Dry flower yield; TC – total carotenoids; TP – total phenolic; TF – total flavonoids; DPPH – DPPH reduction.

Table 7
Elements of matrix W_2 and vector B_2 (presented in the bias column).

	1	2	3	4	5	6	7	8	9	Bias
H	-0.363	4.167	-1.768	-0.910	-3.581	-2.015	-0.077	0.085	-2.509	-0.794
MWP	-3.218	-0.006	0.580	-0.940	1.932	0.506	1.373	0.533	-3.874	-5.480
NFP	0.418	-0.161	-1.271	0.376	2.553	-1.176	-1.158	1.151	0.431	-1.354
AMF	0.370	1.005	-0.154	-1.112	-0.614	-0.929	-0.879	-0.641	-0.280	0.855
MFP	1.598	1.764	-1.053	0.861	-0.096	-0.910	2.033	-2.279	0.943	-1.324
DF	-1.677	-0.039	1.074	-0.703	-1.111	0.362	1.138	0.178	0.593	-1.098
FY	0.925	-1.213	-1.047	-2.007	-0.899	-1.101	-2.194	-0.452	-0.282	-1.351
DY	2.244	-1.330	1.217	0.478	-0.934	0.873	-3.018	1.166	-0.100	-1.348
TC	-0.780	1.196	-1.595	-1.098	0.382	-0.652	0.548	1.696	0.147	-0.646
Tphen	-1.160	-0.980	-1.394	-0.068	-1.110	-1.978	-0.825	-3.218	-0.202	-1.257
Tflav	-2.747	0.785	0.924	-2.469	0.862	0.475	2.531	0.220	-0.479	0.080
DPPH	0.256	-0.905	-1.400	2.523	-0.729	-1.121	-0.830	1.940	-1.284	-0.753

H – Plant height; MWP – Mass of the whole plant; NFP – Number of flowers on plant; AMF – The average mass of the flower; MFP – Mass of flowers per plant; DF – Flower diameter; FY – Fresh flower yield; DY – Dry flower yield; TC – total carotenoids; TP – total phenolic; TF – total flavonoids; DPPH – DPPH reduction.

Table 8
The "goodness of fit" tests for the developed ANN model.

	χ^2	RMSE	MBE	MPE	R^2	Residual analysis			
						Skewness	Kurtosis	Average	SD
H	21.279	3.859	-0.398	6.106	0.780	-0.798	1.798	-0.398	3.888
MWP	4433.699	55.710	-10.984	13.334	0.674	-1.929	4.042	-10.984	55.312
NFP	17.202	3.470	0.445	13.331	0.929	1.348	2.899	0.445	3.485
AMF	0.004	0.054	-0.010	7.635	0.945	-0.621	0.624	-0.010	0.053
MFP	14.484	3.184	0.509	24.995	0.952	0.203	2.155	0.509	3.183
DF	0.900	0.794	0.104	11.669	0.877	0.120	-0.053	0.104	0.797
FY	1.6E + 06	1.1E + 03	1.9E + 02	24.736	0.952	0.148	2.275	1.9E + 02	1.1E + 03
DY	6.0E + 04	2.0E + 02	1.9E + 01	25.314	0.950	0.249	2.043	1.9E + 01	2.1E + 02
TC	1.253	0.936	0.084	23.194	0.535	1.349	2.379	0.084	0.945
TP	76.315	7.309	0.792	17.307	0.701	0.419	-0.621	0.792	7.358
TF	22.929	4.006	0.419	16.006	0.842	1.553	2.508	0.419	4.035
DPPH	233.070	12.773	1.561	11.702	0.235	0.146	-0.714	1.561	12.839

H – Plant height; MWP – Mass of the whole plant; NFP – Number of flowers on plant; AMF – The average mass of the flower; MFP – Mass of flowers per plant; DF – Flower diameter; FY – Fresh flower yield; DY – Dry flower yield; TC – total carotenoids; TP – total phenolic; TF – total flavonoids; DPPH – DPPH reduction.

and the guidelines of the European Green Deal and its accompanying strategies. In this way, a farm or manufacturing facility provides high-quality organic fertilizer, and achieves the desired ecological and economic effect. The results show that using compost from medicinal plants on marigold improved the productive and qualitative traits of plants as if they were fertilized with commercial fertilizer. Research shows that compost from waste of the production and processing of medicinal plants and application can be an alternative to other organic and conventional fertilizers.

CRediT authorship contribution statement

Vladimir Filipović: Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Vladan Ugrenović:** Conceptualization, Investigation, Resources, Project administration. **Vera Popović:** Formal analysis, Data curation, Writing – original draft, Project administration. **Snežana Dimitrijević:** Formal analysis, Project administration. **Slobodan Popović:** Formal analysis, Project administration. **Milica Aćimović:** Data curation, Supervision. **Ana Dragumilo:** Writing – original draft, Supervision. **Lato Pezo:** Software, Writing – original draft, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

Acknowledgements

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Agreement nos. 451-03-68/2022-14/200003, 200011 and 200032.

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