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Tomato transplants grown on mixtures suitable for organic production

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Summary: One of the main tasks for every certified organic vegetable producer is to grow healthy and well-developed transplants. The aim of this study was to examine different substrates designed for the production of organic tomato transplants. On the basis of preliminary experiments, seven substrates consisting of different parts of natural peat, vermicompost, shrub and tree leaves compost and zeolites were compared with standard commercial substrates using tomato (*Solanum lycopersicum* L.) transplants grown in pots. The data concerning plant height, number of leaves, fresh plant mass, appearance of flower buds were collected. The differences in the examined traits were not significant for the majority of substrates. The zeolite-based substrate with high peat and vermicompost content achieved the best results and its production for the market should be considered. Three zeolite-based substrates with high rates of vermicompost and compost should be used as a model for tomato transplants substrate preparation.
Key words: composts, mixtures, organic farming, peat, substrates, tomatoes, transplants, vermicompost, zeolites

Introduction

One of the main tasks for every certified organic vegetable producer is to grow healthy and well developed transplants and also to follow current legislation and standards concerning organic production (Republika Srbija 2010a; Republika Srbija 2011). For that reason, the majority of organic producers are forced to get certified organic seeds and substrates appropriate for organic production by buying them on the market.

One of the basic principles of organic agriculture states that production must be based on ecological processes, and recycling (IFOAM 2017). Almost all substrates from the National list of fertilizers suitable for certified organic production are peat based only (MPSV 2017). Peat is natural material with high porosity, low specific mass, low levels of salts, highly capable of retaining moisture and nutrients, providing an excellent environment for seed germination and early growth of young plants.

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However, peat accumulation is a slow and long-lasting process (Zaccone et al., 2013; Hansson et al., 2014) and that is the main reason why it is considered as a nonrenewable material.

Recently, the concerns for peat land and peat bogs devastated by human activities as much as conceptions promoting lower environmental footprint and recycling, were inspiration for many scientists to examine different raw materials for peat substitution in transplant production.

Zhang et al. (2012) examined spent mushroom substrate as a peat substitute in substrates for vegetable seedlings production. Ben Janena et al. (2013) studied chicken manure and olive mill residues as a peat substitutes for vegetable seedlings production. Many other kinds of composts, such as forestry waste compost, pig manure compost, slumgum compost, grape marc, green pruning compost and many others were objects of research in numerous studies (Ribeiro et al., 2007; Zmora-Nahum et al., 2007; Carmona et al., 2012; Ben Jenana et al., 2013; Morales-Corts et al., 2014; Meng et al., 2017).

The use of compost is not only preferable as a nutrient source for plants, but is also important in view of waste management, cost savings and ecological footprint for reduced peat consumption. Beside the above mentioned advantages, composts have ability to suppress soil-borne diseases (Raviv 2017; Meng et al., 2017).

Vermicompost is another suitable material for seedlings-substrates preparation and peat substitution. It is the product of bio-waste decomposing, accelerated by different species of earthworms. Some chemical characteristics place it at the top of the most valuable materials for substrate preparation for example, high content of nutrients and the most important, high nutrient availability. Those benefits are especially essential for organic production because it can substitute mineral fertilizers without significant decrease of plant growth and yields. Some studies highlighted the value of VC as a plant disease suppressor (Szczech 1999; Ersahin et al., 2009), but it did not show good results in transplants growing media when its content exceeded 60 % v/v (Zaller, 2007).

The aim of this study was to evaluate different substrate mixtures, based on vermicompost, shrub and tree leaves compost, natural peat and zeolites, under the organic tomato seedlings production.

Materials and Methods

The trial was conducted at the experimental glasshouse with additional heating, located at the experimental field of the Institute of Vegetable Crops in Smederevska Palanka (44°22' N, 20°57' E, 102 m above sea level), Serbia, during the winter-spring season of 2016. On 3 March tomato seeds (*Solanum lycopersicum* L. cv. *Balkan* F1) were sown manually in 104 cells white polystirene trays (2 seeds per cell), filled with a standard commercial substrate (Floragard Semi 1). Balkan F1 is an early maturing hybrid with determinant growth, suitable for greenhouse production as well as production in the open field with intermediary fruits.

During the experiment the trays were watered ordinarily. After germination, the second plant in each tray cell was removed by hand. Natural peat (NP), vermicompost (VC), shrub and tree leaves compost (STLC) and zeolites (ZE) were used for examined substrates preparation.

NP was collected from the Leskova peat bog, Pester plateau, Tutin, Serbia (43°06' N, 20°18' E, 870 m above sea level). It has high organic matter content but the pH value is very low as well as the content of available nutrients. VC is product of red Californian earth worm (*Eisenia fetida* Savigny). The initial material for worm feeding was cow manure mixed with straw and hay residues. It was produced on the local farm near Smederevska Palanka. STLC is composted mixture of grass remains, shredded leaves

Table 1. Chemical analysis, macronutrients, micronutrients and heavy metals content of materials used for substrate preparation (NP – natural peat; VC – vermicompost; STLC – shrub and tree leaves based compost; ZE – zeolites; MPV – maximal permitted values, according to national legislation concerning fertilizers (Republika Srbija 2009); n.a. – not available

Properties	NP	VC	STLC	ZE	MPV
pH (H_2O)	5.5	8.1	8.3	7.35	-
pH (KCl)	4.9	7.3	7.4	na	-
Moisture (%)	40.8	52.16	47.7	4.02	-
Dry matter (%)	59.2	47.84	52.3	95.98	-
Organic matter (%)	89.08	67.62	70.81	0.0	-
Mineral matter (%)	11.92	32.38	29.19	>99.5	-
N (%)	0.65	1.48	0.83	1.0	-
C/N	26.3	13.8	16.8	0	-
P (%)	0.11	1.36	0.91	1.0	-
K (%)	0.08	1.03	1.6	2.7	-
N available (mg/kg)	55	240	n.a.	1×10^4	-
P available (mg/100g)	1	141	n.a.	811	-
K available (mg/100g)	4	3.2×10^3	n.a.	1.8×10^4	-
Ca (%)	0.31	3.1	1.73	3.5	-
Mg (%)	0.2	1.09	0.71	1.5	-
Fe (%)	0.62	1.39	0.85	2.1	-
Mn (mg/kg)	65	470	327	480	-
Zn (mg/kg)	12	125.1	89.4	44	-
Cu (mg/kg)	8	47.5	38.6	6.25	-
Co (mg/kg)	4.2	9	na	29.5	-
Mo (mg/kg)	na	4.75	3.8	17	-
Heavy metals					
Cd (mg/kg)	0.1	0.28	1.3	3.5	75mg/kg P_2O_5
Pb (mg/kg)	5	40.1	61.8	42.5	100
Cr (mg/kg)	22	14.65	48.6	6.5	500
Ni (mg/kg)	48	38.8	52.3	22.5	100
Hg (mg/kg)	na	0.04	na	na	1

and branches of tree species widely grown in the city parks and areas for rest and recreation. These remains are related predominantly to a few tree species such as: lime tree (*Tilia* sp.), maple tree (*Acer* sp.), ash tree (*Fraxinus* sp.), poplar (*Populus* sp.) and silver birch (*Betula pendula* Roth). Shredded remains were composted in compost piles located in open space without additional fertilizers or watering for at least two years. STC was provided by the Communal Company of Novi Sad. ZE are natural aluminosilicate minerals (about 75% clinoptilolites), with large specific surface area (SSA) and a high value of the cation exchange capacity (CEC). In this experiment, ZE from the „Jablanica 1“ deposit near Kruševac (2.0 - 5.0 mm particles size; SSA - 14,2 m^2/g; CEC - 168 meq/100g) was used (Table 1).

Each material was analyzed in the certified chemical laboratory, according to the methods and procedures described in the National rule book concerning procedures, materials and methods for determination of macronutrients, micronutrients and heavy metals content in fertilizers and soil enhancers, as well as Belgrade's University handbook for agrochemical analysis (Republika Srbija 2010b; Džamić et al., 1996).

In our previous trials, these materials were examined according to standard procedure (Damjanović et al. 1994, Damjanović et al. 2005), which uses the graded mixtures of each material and commercial substrates to check possibility of its application as an ingredient for transplants growing media (data not shown). Previous evaluations of materials were performed by considering phytotoxic effects, symptoms of nutrient deficiency, plant height, number of leaves, fresh root, stem and leaves mass.

Based on the above mentioned trials, seven different mixtures (M1-M7), with content of nonrenewable ingredients exactly or less than 50%, were prepared for testing (Table 2).

Following the appearance and development of the first regular leaf, the seedlings were transplanted in the seven examined substrates and three commercial substrates which are used as control treatments S1-S3.

S1 and S2 commercial substrates are the products of Klasmann Deilmann company, prepared by mixing white and black peats with additional fertilizers. S3 commercial substrate is the product of Floragard Vertriebs company, prepared according to their own recipe with usage of natural peat, mineral and organic fertilizers. The basic chemical properties of commercial substrates are shown in the Table 3.

Ten experimental pots (9 cm in diameter) in three replications were filled with one of the seven tested mixtures and one of the three commercial growing media (300 pots total). Appropriately developed plants were transplanted using latex gloves, in to the filled pots at the depth equal to the previous one, i.e. equal to the depth in the polystyrene trays. Transplanted plants were watered regularly until the end of experiment. Additional fertilizers were not used during the trial and plants' demands for nutrients were fulfilled only by examined commercial and mixed substrates. Plant diseases and harmful pests were not noticed so the experimental plants were not treated with any pesticides.

On 25 April, after 52 days of nursery treatment the plants were picked up from pots and the samples of 10 plants per treatment replication were formed. Each plant root was washed carefully with tap water in order to

Table 2. Volumetric ratio of constituent materials for each examined substrate mixture (NP – natural peat; VC – vermicompost; STLC – shrub and tree leaves based compost; ZE – zeolites)

Mixtures	NP	VC	STLC	ZE
	v/v %			
M 1	33	33	33	-
M 2	40	30	30	-
M 3	30	20	30	20
M 4	30	30	20	20
M 5	30	25	25	20
M 6	20	30	30	20
M 7	25	25	25	25

Table 3. Basic chemical properties of used commercial substrates (S1 - Klasmann KTS 2; S2 - Potgrond H; S3 - Florabalt Plus PV2)

Properties	S1	S2	S3
pH (H_2O)	6.1	6.3	6.4
N (mg/l)	320	210	240
P (mg/l)	370	240	192
K (mg/l)	410	270	262
Ca (mg/l)	490	715	785
Mg (mg/l)	85	85	90

remove the particles of substrates and to keep the root parts preserved. Following the procedure, excessive water drops were gathered with filter paper.

Plant height was measured with a ruler. Number of leaves per plant and flower bud appearance rate were counted and calculated per sample replication. The flower bud appearance rate represents the number of plants with flower bud per hundred plants examined (percentage of plants with developed flower buds). Root, stem and leaves mass were measured with a technical precision scale. Based on the collected data, one way ANOVA was performed, using Windows Excel 2003 and the Duncan's test was performed for comparison of means. Flower bud appearance data were transformed by arcsine $\sqrt{(x/100)}$ prior to analysis.

Results and Discussion

In our experiment, the examined mixtures and standard (commercial) growing media showed variations of observed traits (Table 4). During the experiment performance, the presence of symptoms concerning malnutrition, nutrient deficiency or phytotoxic effects for any treatment was not recorded.

Plant height ranged from 21.53 to 32.07 cm, and the statistically significant differences between treatments were noticed (Table 5). The highest plants were formed on the mixtures containing ZE, but only the mixture M4 was significantly higher than all examined standard growing media (S1-S3). While the plants grown in mixtures with ZE were significantly higher than those grown in standard substrates S2 and S3, the differences between standard growing media S1 and zeolite based mixtures (except M4) were not significant. Using compost, peat and traditional mixtures for growing media preparation, Atif et al. (2016) recorded average tomato seedlings height from 19.1 to 35.0 cm. According to Ilin et al. (2003), the average height for well-developed tomato transplants should be between 20 and 35 cm. Different composts could improve tomato plant and transplant height (Gutierrez-Miceli et al., 2007; Herrera et al., 2008). The same case is for ZE (Damjanović et al. 2005). Higher plants recorded on ZE based substrates with high VC content are probably the result of the nutrient content and its availability in such materials (Table 1).

The average number of leaves ranged from 5.87 (M2) to 6.9 (M4). The highest value of this trait was achieved with treatment M4, which differed significantly when compared with all other treatments. On the other side, under average number of leaves were recorded for treatments M1 and M2, which showed statistical difference compared to commercial substrates (S1-S3) and ZE based mixtures. The number of leaves per plant depends on plant density, season, temperature, nutrition and growth stage, so the plants sampled on the same date can have different number of leaves (Damjanović et al., 2005; Heuvelink 2005; Kang et al., 2011). As some of the earlier studies showed (Damjanović et al., 2005; Lazcano et al., 2009) and our results confirmed, the application of vermicompost and compost in some volume ratios could enhance the number of leaves per plant (Table 5).

Average values of fresh plant mass for different growing media mixtures (M1-M7) and standard substrates (S1-S3) are shown in Figure 1. Greatest fresh plant mass, significantly different from all other treatments, was recorded for the ZE based mixture with high NP and VC content (M4). For the other ZE based mixtures, the plant mass achieved was without significant difference compared to commercial substrate S1. Significantly different under-average values of fresh plant mass were recorded for two commercial substrates (S2 and S3), as well as for two mixtures without ZE (M1 and M2). Above mentioned data were in accordance with results of Ilin et al. (2002 and 2003) who examined different substrates and Meng et al. (2017) who noticed the increment of tomato transplants' fresh plant mass when different amounts of compost were used.

Contrary to prior traits, the highest value of average root mass was recorded for one of the standard substrates S1 (Table 4). Root mass in case of S1 substrate differed significantly from all others treatments, as well as the root mass for M4 mixture, the second largest value. The least value with significant difference compared to all others treatments was recorded for M3 mixture. The majority of mixtures (M1, M2, M5, M6, and M7) and commercial substrates (S2 and S3) did not differ significantly from each other. Enriched zeolites contain high amounts of available nutrients. According to some studies, the root mass decreases when ZE are added to growing media for tomato transplants cultivation (Pavlović 2000; Damjanović et al., 2005; Damjanović et al., 2006). Our results are compatible with these findings.

The greatest stem mass was recorded for zeolite based mixture with high NP and VC content (M4). It

Table 4. Mean squares (MS) from ANOVA for the analyzed tomato transplant traits

Effect	Degrees of freedom	Plant height	No of leaves	Root mass	Stem mass	Leaves mass	Flower bud appearance rate
Treatment	9	38.831**	0.232**	0.019**	3.451**	1.828**	0.178**
Error	20	3.557	0.037	0.001	0.065	0.055	0.020

*, ** – significant at the 0.05 and 0.01 levels of probability, respectively

Table 5. Average values of examined traits for different growing media mixtures (M1-M7) and standard substrates (S1-S3)

Treatments	Plant height (cm)	Number of leaves	Root mass (g)	Stem mass (g)	Leaves mass (g)	Flower bud appearance rate (%)
M 1	21.53[a]	5.97[a]	0.504[ab]	1.178[a]	1.533[a]	0[a]
M 2	24.9[ab]	6.03[ab]	0.518[ab]	1.305[a]	1.63[ab]	0[a]
M 3	27.87[bc]	6.27[abcd]	0.476[a]	3.179[c]	2.787[c]	10.0[bc]
M 4	32.07[e]	6.9[e]	0.633[c]	3.918[d]	3.909[d]	36.7[d]
M 5	28.2[bcd]	6.4[cd]	0.499[ab]	3.39[c]	3.02[c]	23.3[cd]
M 6	29.13[cde]	6.53[d]	0.532[ab]	3.236[c]	2.854[c]	30[d]
M 7	31.43[de]	6.37[bcd]	0.517[a]	3.296[c]	2.867[c]	26.7[d]
S 1	28.4[cd]	6.27[abcd]	0.738[d]	2.6[b]	2.733[c]	6.7[ab]
S 2	23.4[a]	6.13[abc]	0.543[b]	1.428[a]	1.94[b]	3.3[ab]
S 3	23.1[a]	6.07[abc]	0.489[ab]	1.241[a]	1.59[a]	0[a]

Values within the same column followed by the same letter do not differ significantly at the 0.05 level of probability, according to Duncan's test

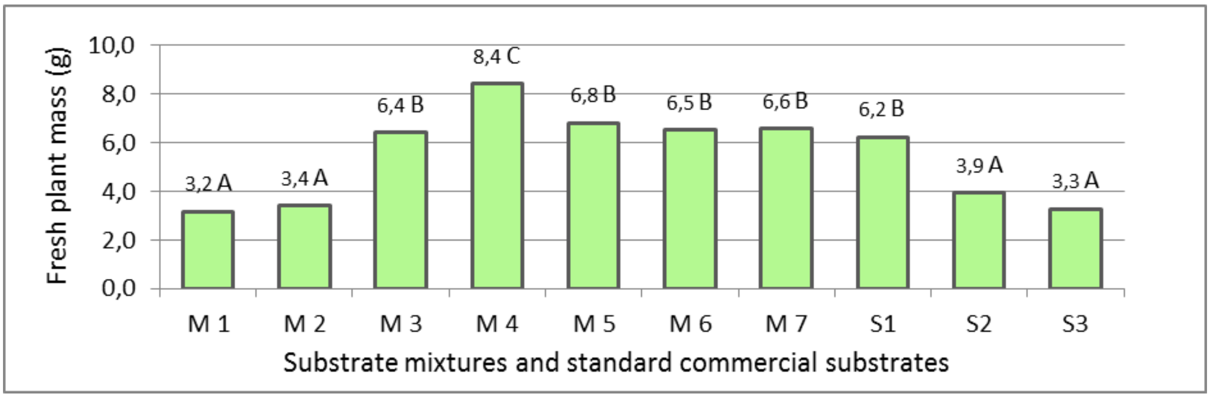

Figure 1. Fresh plant mass (g) for different substrate mixtures (M1-M7) and standard commercial substrates (S1-S3). Values followed by the same letter do not differ significantly at the 0.05 level of probability, according to Duncan's test

was significantly different in comparison to all other treatments (Table 4). Other ZE based mixtures also achieved significantly higher values of stem mass compared to standard substrates (S1-S3) and remaining mixtures (M1-M2), which did not differ significantly from one another (except S1). It is in accordance with results of Damjanović et al. (2005), who recorded higher tomato stem mass for substrates with added zeolites.

The greatest leaves mass, significantly different when compared to all other treatments, was also recorded for ZE based mixture with high NP and VC content (M4). Same as for the stem mass, ZE based mixtures achieved significantly different values when compared to commercial substrates and remaining mixtures (M1 and M2). Our results are in accordance with findings of Damjanović et al. (2005) but opposite to findings of Ribeiro et al. (2007), who recorded higher tomato seedlings shoot and root mass for substrate mixtures with higher content of compost obtained from forestry.

Flower bud appearance rate also varied significantly. The least value was 0% for mixtures without ZE and commercial substrate S3, but the mentioned treatments did not differ significantly from the other two commercial substrates (S1 and S2). On the other side, significantly higher flower bud appearance rate was recorded for ZE based mixtures (except M3). Highest flower bud appearance rate (36.7%). was achieved with ZE based mixture with high NP and VC content (M4). As the number of leaves per plant, the flower bud appearance trait is in correlation with amount of accumulated organic matter in the plant which is subjected to plant density, season and other environmental effects (Kang et al. 2011). The appearance of flower buds is linked with number of developed leaves and depends mostly on genotype (Huevelink 2005; Zdravković et al. 2012). For tomato genotypes with indeterminate growth, flower buds appear after eight to ten developed leaves and for genotypes with determinate growth, flower buds appear after six or seven developed leaves. Early maturing hybrid Balkan F1 used in our study started bud appearance after six or seven leaves, which is in accordance with cited authors (Huevelink 2005; Zdravković et al. 2012).

Conclusions

Compared to the commercial substrates, for the majority of mixed growing media, the differences in examined traits were not significant. However, the application of ZE, VC and STLC in specific ratio could increase the plant height, number of leaves, steam and leaves mass and promote flower bud appearance. This is very important in case of organic production, because the addition of mineral fertilizers is not allowed and there is a lack of registered fertilizers capable to effectively improve plant nutrition during the transplant period. Three ZE based mixtures with high rates of VC and STLC should be used as a model for growing media preparation. For as much as the ZE based mixture with high NP and VC content achieved the best results, its certification and production for market should be considered.

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Supstrati za organsku proizvodnju rasada paradajza

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Sažetak: Jedan od glavnih zadataka svakog sertifikovanog proizvođača organskog povrća je da odgaji dobro razvijen rasad. Ispitivanje različitih supstrata dizajniranih za organsku proizvodnju rasada paradajza bio je glavni cilj ovog istraživanja. Na osnovu rezultata prethodnih istraživanja, pripremljeno je sedam smeša supstrata sastavljenih od različitih udela prirodnog treseta, glistenjaka, kompostiranog lišća drveća i žbunja i prirodnih zeolita i upoređeno sa standardnim komercijalnim supstratima. Prikupljeni su podaci koji su se odnosili na visinu biljke, broj listova po biljci, masu sveže biljke i pojavu cvetnih pupoljaka. Za većinu ispitivanih mešavina zabeležene razlike nisu bile statistički značajne u poređenju sa komercijalnim supstratima. Kod mešavine supstrata na bazi zeolita sa visokim sadržajem treseta i glistenjaka zabeleženi su najbolji rezultati. Ova smeša bi mogla da bude ponuđena kao gotov proizvod na tržištu. Tri smeše na bazi zeolita sa visokim sadržajem glistenjaka i komposta trebalo bi da posluže kao model za pripremu supstrata namenjenih sertifikovanoj organskoj proizvodnji.

Ključne reči: glistenjak, kompost, organska proizvodnja, paradajz, rasad, smeše, supstrati, treset, zeolit

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