Compost as growing media component for salt-sensitive plants

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ABSTRACT

Composting has been considerably recognized as a viable management method for solid organic wastes aimed at recycling of its end-product as a potting substrate for ornamental plants. *Pelargonium* and *Salvia* as salt-sensitive plants were grown in the mixture of compost (75, 50, 25% by volume) and additives (Hygromull, Cocofiber and SPS-standard soil type 73 with 70% peat and 30% clay). Since plants may suffer from a high salt content, thus in a further experiment compost was added as a partial substitute for peat. The results of the first pot experiment reveal that the large percentage of compost in the substrate had negative effects on plant growth and nutrient uptake (N, P, K and Na). Both yield formation and nutrient uptake significantly increased and almost gained levels of those in the control in the second pot experiment when plants were grown in peat-based substrates. Especially, the growth of *Salvia* was significantly improved. Consequently, the compost-based media (> 50% volume of compost) cannot be recommended for salt sensitive ornamental plants, while less than 25% of compost incorporated into peat creates peat-based substrates which reasonably enhanced growth of *Pelargonium* and *Salvia*.

Keywords: ornamental plants; peat; additives; nutrient uptake; plant growth

Peat as a traditional substrate was considered as the best option to gain the optimum quality and yield for ornamental cultivation (Robertson 1993). However, scientists have recognized the importance of finding available peat constitution for the purpose of ecological nature resource conservation, less peat dependence and sustainable agricultural development since the late 1990s (Alexander et al. 2008). An endless organic sources as an alternative for peat is composts generated from biosolids, municipal solid wastes or green wastes. So far, composts originating from different organic wastes were considered as a beneficial and excellent partial substitution for peat in term of its high abundance and as an improver of soil characteristics and plant growth in horticulture (Grigatti et al. 2007, Oberpaur et al. 2010).

Numerous experiments with combinations of peat and compost sourced from multiple organic wastes mixed at different proportions were conducted for various plant species (Fischer and Schmitz 1997, Mami and Peyvast 2010). Additionally, additives with low nutrient contents and soluble salts as well as stable structure such as crushed brick, bark, wood chips (Fischer and Popp 1998), inert products like polyurethane-ether, perlite, foam-plastics, polystyrene and vermiculite (Boodt and Verdonck 1971, Lamanna et al. 1991) could be suitable to be added to compost and peat mixtures to improve the physical characteristics and reduce the peat proportion.

This study was conducted to investigate the suitability of compost-based and peat-based substrates to be used as potting media for ornamental plants and to develop optimal growing conditions for growth and quality of salt-sensitive plants. In order to address these objectives, two pot experiments were conducted. Experiment 1 was aimed at

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studying the effects of compost-based media with high salt content on yield formation and nutrient uptake, while the experiment 2 was targeted to produce peat-based substrates as standard soils with a moderate salt content to optimize ornamental values for the tested sensitive plants, *Pelargonium* and *Salvia*.

MATERIAL AND METHODS

Raw materials. The chemical characteristics of compost, standard soils composed of mainly white peat and partially black peat as the control (TKS_1 and TKS_2), TKS_0 produced from 100% white peat without supplement of nutrient salts and standard soil substrate type ED 73 (SPS) are shown in Table 1. Additionally, additives were incorporated according to the experimental design. Hygromull (Hy) and Cocofiber (Coco) were chosen as additives for the first experiment containing a high content of available P and exchangeable K, while Styromull (Sty) and Perlite (Per) were used in the second experiment.

Experiment 1: Compost-based susbtrates. TKS_1 was used as the control potting substrate for *Salvia* and TKS_2 for *Pelargonium*. To compost as the main substrate some additives including standard soil substrate type ED 73 (SPS), Coco and Hy were added to decrease the salt content of pure compost. SPS comprised of 70% white peat and 30% clay. Ten treatments with 4 replications were established in the greenhouse of INRES-Plant nutrition, Bonn University, Germany (Table 2).

Experiment 2: Peat-based substrates. As the control the same potting substrates were used as in experiment 1. TKS_0 produced from 100% white peat was used as main substrates in pots while compost was added as an additive fertilizer. Peat was pretreated with a solution (volumetric ratio of moistening solution and peat = 1.47/100) containing Mg plus micronutrients (based on FERTY® 10, Planta Düngemittel GmbH, Regenstauf, Germany) containing 6% Mg, 0.5% B, 2% Cu, 3.5% Fe, 0.5% Mn, 0.8% Mo and 0.3% Zn (5.1 g/L)) and limestone $CaCO_3$ (3.5 g/L). This preparation method was described similarly by Olympios (1992). Styromull (Sty) and Perlite (Per) containing no salt and no nutrients were the additives. Experiment 2 included eight treatments with 4 replications (Table 3).

Pot experiments. The moderately salt-sensitive *Salvia* (*Salvia splendens*) and the less salt-sensitive *Pelargonium* (*Pelargonium zonale*) were chosen as experimental plants.

Plants (one plant/pot) were transplanted in 6 L pots (diameter: 25 cm, height: 30 cm) and watered with distilled water every day (50% maximum water holding capacity). After 60 days, plants were harvested. Fresh plant material including flowers and leaves was dried at 60°C in a thermal oven until constant dry mass, finely ground into powder and stored in plastic bottles until analysis.

Analysis methods. For compost and standard soils, parameters including dry matter (DM), pH ($CaCl_2$), salt content (E_c), available P and K, total N, P, K, Na, and C and for plant materials N, P, K and Na content were determined according to the standard methods of VDLUFA (Hoffmann

Table 1. Chemical characteristics of compost, standard soils and additives

Parameters	Compost	TKS_0	TKS_1	TKS_2	SPS	Coco	Hy
DM (%)	47.0	50.1	54.7	59.3	49.5	83.4	0.0
pH ($CaCl_2$)	7.2	5.6	5.3	5.4	5.9	4.5	2.6
E_c (mS/cm)	3.09	0.36	0.92	2.94	0.20	0.38	0.69
P_{total} (mg/kg)	3 887	212	621	1 060	449	376	10 238
CAL-P (mg/kg)	1 410	25	263	742	89	194	10 574
K_{total} (mg/kg)	12 117	850	1 273	2 967	1 500	10 800	20 833
CAL-K (mg/kg)	1 773	77	163	419	205	11 396	8 180
Na_{total} (mg/kg)	2 776	216	317	427	176	2373	969
N_{total} (%)	1.89	0.74	0.84	0.79	0.40	0.39	26.49
C_{total} (%)	21.00	46.08	49.06	48.20	19.10	45.85	29.57

Samples were analyzed with three replicates and average values are presented. TKS_0, TKS_1, TKS_2, SPS – standard soils; Coco – cocofiber; Hy – Hygromull

Table 2. Treatments of experiment 1

No.	Treatment	Potting substrate	WHC (%)
1	control	standard soil: TKS_1 for *Salvia*	145.2
		standard soil: TKS_2 for *Pelargonium*	160.7
2	Comp	100% compost	32.3
3	Comp/SPS 4:1	80% compost + 20% standard soil type ED 73	37.3
4	Comp/SPS 1:1	50% compost + 50% standard soil type ED 73	60.3
5	Comp/SPS 1:4	20% compost + 80% standard soil type ED 73	67.3
6	Comp/Coco 4:1	80% compost + 20% Cocofiber	29.5
7	Comp/Coco 1:1	50% compost + 50% Cocofiber	24.1
8	Comp/Coco 1:4	20% compost + 80% Cocofiber	43.2
9	Comp/Hy 4:1	80% compost + 20% Hygromull	41.7
10	Comp/Hy 1:1	50% compost + 50% Hygromull	71.7

Comp – compost; TKS_0, TKS_1, TKS_2, SPS – standard soils; Coco – cocofiber; Hy – Hygromull. Hygromull with its density of 35–40 kg/m^3 was impossible to set up the mixture of Compost and Hygromull (Comp/Hy ratio = 1:4) as other mixtures, because the ideal bulk density for growing substrates should be about 150–500 kg/m^3 (Nappi and Barberis 1993); WHC – water holding capacity

1991, 1995, 1997). Total nutrient uptake (mg/pot) is determined by nutrient content (mg/g DM) × dry matter (g/pot).

Statistical analyses. Multivariate analysis (ANOVA) was performed using the SPSS 18.0 software package (Chicago, USA). Means of DM, total uptake of nutrients in plant materials were compared at significance level of P = 0.05 by the Tukey's test throughout the study.

RESULTS AND DISCUSSIONS

Experiment 1: Compost-based substrates

Plant growth. Dry matter yield of *Pelargonium* and *Salvia* was highest in the control treatments (TKS_2 and TKS_1) and lowest in 100% compost (Figure 1). Yield of both plants increased significantly with an increasing share of SPS. However, plant growth could not reach that in the control. While with *Pelargonium* the addition of Cocofiber and Hygromull partially favoured yield formation as compared to the pure compost, growth of *Salvia* was not favoured. It is assumed that the high salt content in compost as the main substrate component negatively affects plant growth (Papafotiou et al. 2004). Furthermore, Cocofiber resulted in a highly porous, less water holding substrate which may tend to partially leach nutrients from the potting material. In addition, Hygromull with a relatively high salt content negatively affected plant growth. Therefore both additives are not recommended.

The results concerning yield formation are in agreement with the results of Fischer and Popp (1998) or Grigatti et al. (2007), who investigated the impact

Table 3. Treatments of experiment 2

No.	Treatment	Potting substrate	WHC (%)
1	control	standard soil: TKS_1 for *Salvia*	145.2
		standard soil: TKS_2 for *Pelargonium*	160.7
2	Comp	100% compost	32.3
3	TKS_0/Comp 3:1	75% standard soil from 100% peat + 25% compost	105.7
4	TKS_0/Comp 6:1	86% standard soil from 100% peat + 14% compost	123.3
5	TKS_0/Comp 6:1 + 5% Sty	81% standard soil from 100% peat, 14% compost + 5% Styromull	118.0
6	TKS_0/Comp 6:1 + 10% Sty	76% standard soil from 100% peat, 14% compost + 10% Styromull	120.0
7	TKS_0/Comp 6:1 + 5% Per	81% standard soil from 100% peat, 14% compost + 5% Perlite	124.8
8	TKS_0/Comp 6:1 + 10% Per	76% standard soil from 100% peat, 14% compost + 10% Perlite	125.3

For more details see Table 2

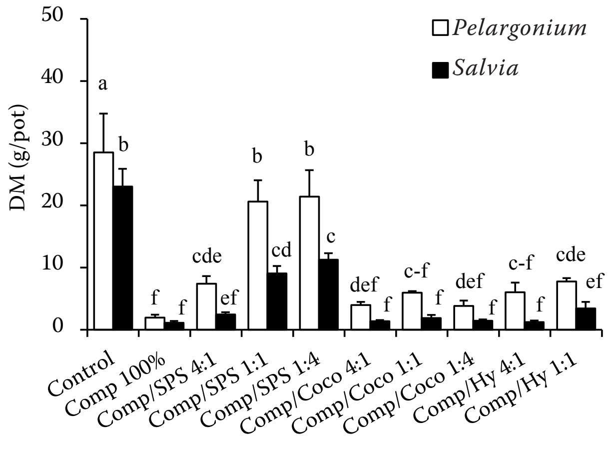

Figure 1. Dry matter yield of *Pelargonium* and *Salvia* grown in compost-based substrates. Error bars represent the standard deviation of 4 replicates. Means of different treatments followed by the same letters are not significantly different ($P < 0.05$) by the Tukey's test. Comp – compost; SPS – standard soils; Coco – cocofiber; Hy – Hygromull

of the share of compost (25%) from anaerobically treated refuse with dry fermentation or green wastes and sewage sludge mixed with peat on growth of *Deuzia scabra* or *Salvia splendens*, respectively. In contrast, Klock-Moore (2000) found that the compost from seaweed with a high initial salt content added at 0, 30, 60 and 100% by volume caused no depression on *Salvia* growth and produced salable quality of *Salvia* flowers. According to Ostos et al. (2008), compost-based substrates with the presence of up to 40% compost from sewage sludge strongly enhanced biomass weight of the shrub *Pistacia lentiscus* L., which was significantly higher than that grown in the commercial peat substrate as the control. Wilson et al. (2001, 2002, 2003) conducted several experiments with peat-based soilless media amended with 25, 50, 75, 100% compost from biosolids and yard trimmings to examine the growth of 24 ornamental perennials including *Salvia*. Even with the high share of compost (50–100%) positive effects on plant growth, flowering or visual quality could be observed. The diverse results among studies on compost-based substrates are assumed to be due to the differences of sources of compost and plant species having different salt tolerance, respectively (Grigatti et al. 2007).

Total nutrient uptake (N, P, K and Na). Total nutrient uptake of both plants from almost all treatments including pure compost and additive-mixed composts, except the Comp/SPS mixtures with the volumetric ratios of 1:1 and 1:4, were statistically not different and had the lowest levels in comparison to the control treatments (Figure 2). Among these compost treatments, the highest total nutrient uptake of both plant species was observed in the mixtures of 20%, followed by 50% compost and SPS, reaching close the level of the control. Notably, total Na uptake of *Salvia* from these mixtures (Comp/SPS with mixing ratios of 1:1 and 1:4) was estimated as 142.2 and 127.1 mg/pot (Figure 2D), respectively. As compared to the other treatments it is significantly higher and is in the range of the control. However, it should be pointed out that total Na uptake of those two compost treatments is not the result of a high Na content (data not shown), but of the high yield formation. On the other hand side the Na content of the other compost treatments was high, resulting in a yield depression (Martinéz et al. 2012) followed by a low total Na uptake. In the literature, the mixture of 40% compost originated from pine bark and moss was found as potential and adequate growing materials for lettuce (*Lactuca sativa*) (Oberpaur et al. 2010), or compost-based substrates with 40% compost from sewage sludge or municipal solid wastes significantly increased nutrient concentrations and total nutrient uptake of the shrub *Pistacia lentiscus* L. (Ostos et al. 2008). However, the authors only mentioned the positive results when mixing 40% compost as the main component and peat substitution, while other applied percentages of compost in compost-based substrates probably resulted in unknown effects on plant growth and nutrient uptake. In our study, the large proportion of compost incorporated into potting materials caused some damages, which had negative effects on the development and quality of the salt-sensitive plants *Salvia* and *Pelargonium*. The same negative effects were recorded for *Poinsettia* production when replacing over 37.5% volumetric peat by olive-mill waste compost (Papafotiou et al. 2004).

On the other hand, the presence of Hygromull or Cocofiber with different proportions in the growing media, despite partially salt content dilution and water holding capacity enhancement, seemed to depress the growth of *Salvia* and *Pelargonium*.

Thus total nutrient uptake was not obviously improved when plants grew on SPS-incorporated compost. Therefore, based on the results of this experiment the addition of Hygromull or Cocofiber to compost may not be recommended. In brief, both ornamental plants *Pelargonium* and *Salvia*,

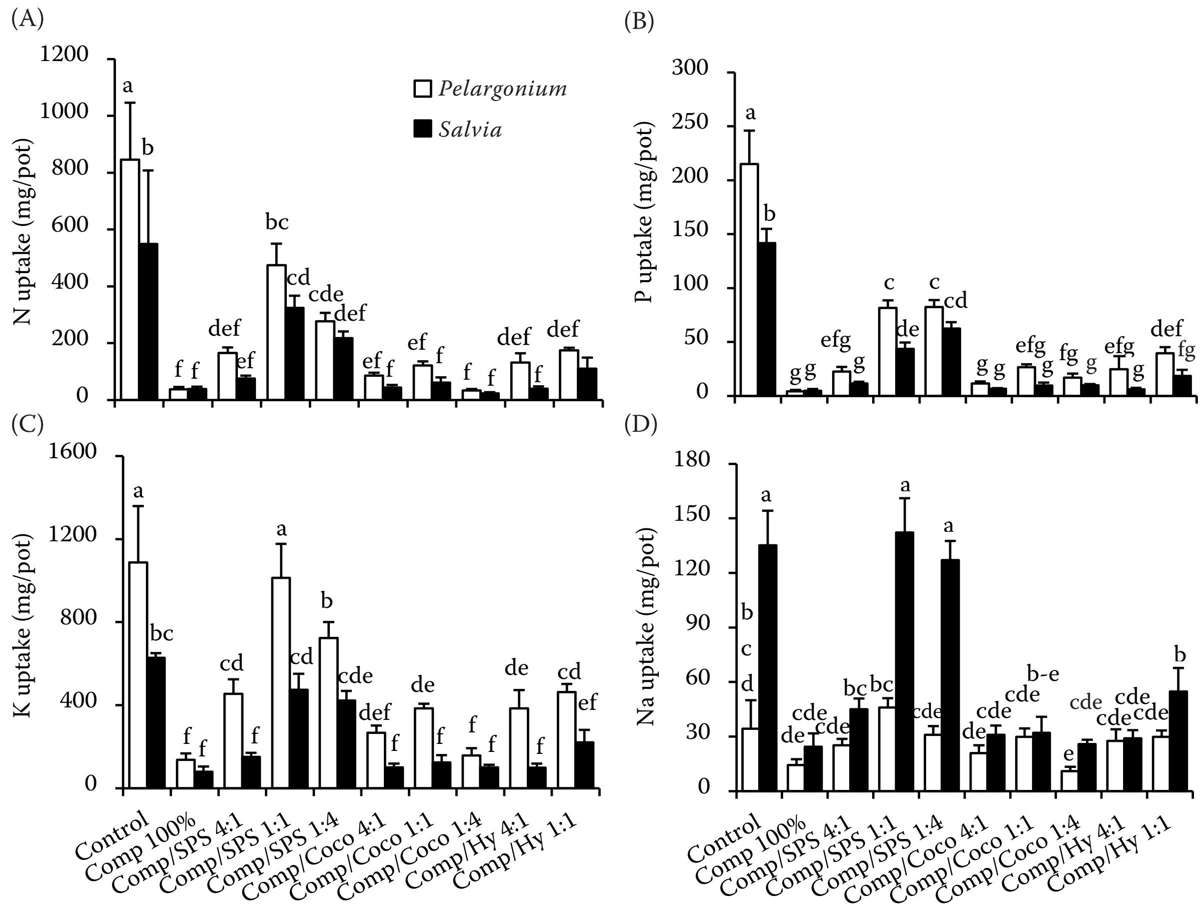

Figure 2. (A) Total N uptake; (B) total P uptake; (C) total K uptake and (D) total Na uptake of *Pelargonium* and *Salvia* grown in compost-based substrates. Comp – compost; SPS – standard soils; Coco – cocofiber; Hy – Hygromull. For more details see Figure 1

grown in the compost-based media with a share of > 50% compost suffered from the high salt content which negatively affected plant growth and nutrient uptake. Therefore, the second experiment was conducted with the same experimental plants, grown in peat-based substrates.

Experiment 2: Peat-based substrates

Plant growth. Dry matter yield of both plants was highest in the control and negligible in the pure compost treatment (Figure 3). In peat-based treatments DM yield of both plants was close to the yield of the control. In comparison with the results of experiment 1, yield formation and ornamental value of *Pelargonium* or *Salvia* cultivated in substrates, containing 25% and 14% volume of compost, respectively, was remarkably improved. However, differences among peat-based treatments were insignificant indicating that the presence of additives Styromull or Perlite in these mixtures had only slight effects on plant growth. Confirming the results of Papafotiou et al. (2004), who pointed out that mixtures containing 12.5% olive mill waste compost produced poinsettia of market quality, we achieved marketable salt-sensitive ornamentals when 14–25% of peat was replaced by compost.

Total nutrient uptake (N, P, K and Na). Similar to DM results, total nutrient uptake of the two plant species cultivated in 100% compost was negligible (Figure 4), which is due to their poor growth, while the incorporation of 14% and 25% compost, respectively, into peat-based substrates resulted in a remarkable enhancement. Among all treatments total uptake of N, P and K of both experimental plants was highest in the control, while total Na uptake of *Pelargonium* and *Salvia* of the control was figured out to be in the same range as the peat-based treatments. Despite the lower

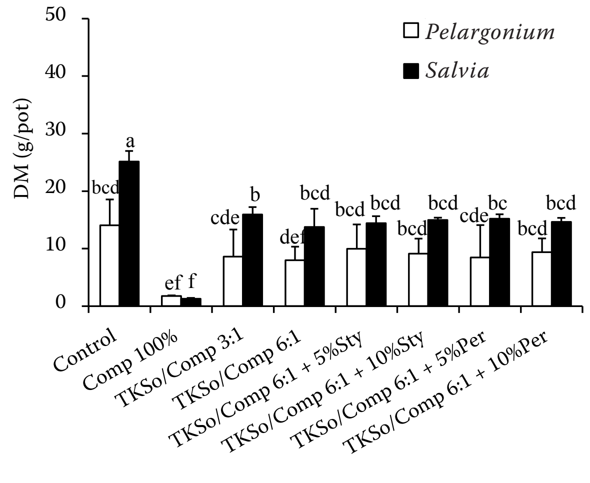

Figure 3. Dry matter yield of *Pelargonium* and *Salvia* grown in peat-based substrates. Error bars represent the standard deviation of 4 replicates. Comp – compost; TKS_0 – standard soils; Sty – Styromull; Per – Perlite. For more details see Figure 1

total nutrient uptake observed in the TKS_0-based treatments, *Pelargonium* and *Salvia*, respectively, achieved marketable values in term of ornamental production. Total Na uptake of *Salvia* increased significantly as compared to the result of the first experiment. This reflects the better adaptation and yield formation of plants when cultivated in peat-based substrates as compared to the compost-based ones. Otherwise, total Na uptake of *Pelargonium* from all treatments including the control, pure compost and TKS_0-based substrates treatments was significantly low in the range of 3.9–19.8 mg/pot (Figure 4D). This proves a less influence of the salt level of the growing medium on the growth of *Pelargonium*.

On the other hand, there was no significant difference of the total nutrient uptake between peat-based treatments without or with the presence of additives such as Styromull or Perlite. These results were similar to the results of experiment 1

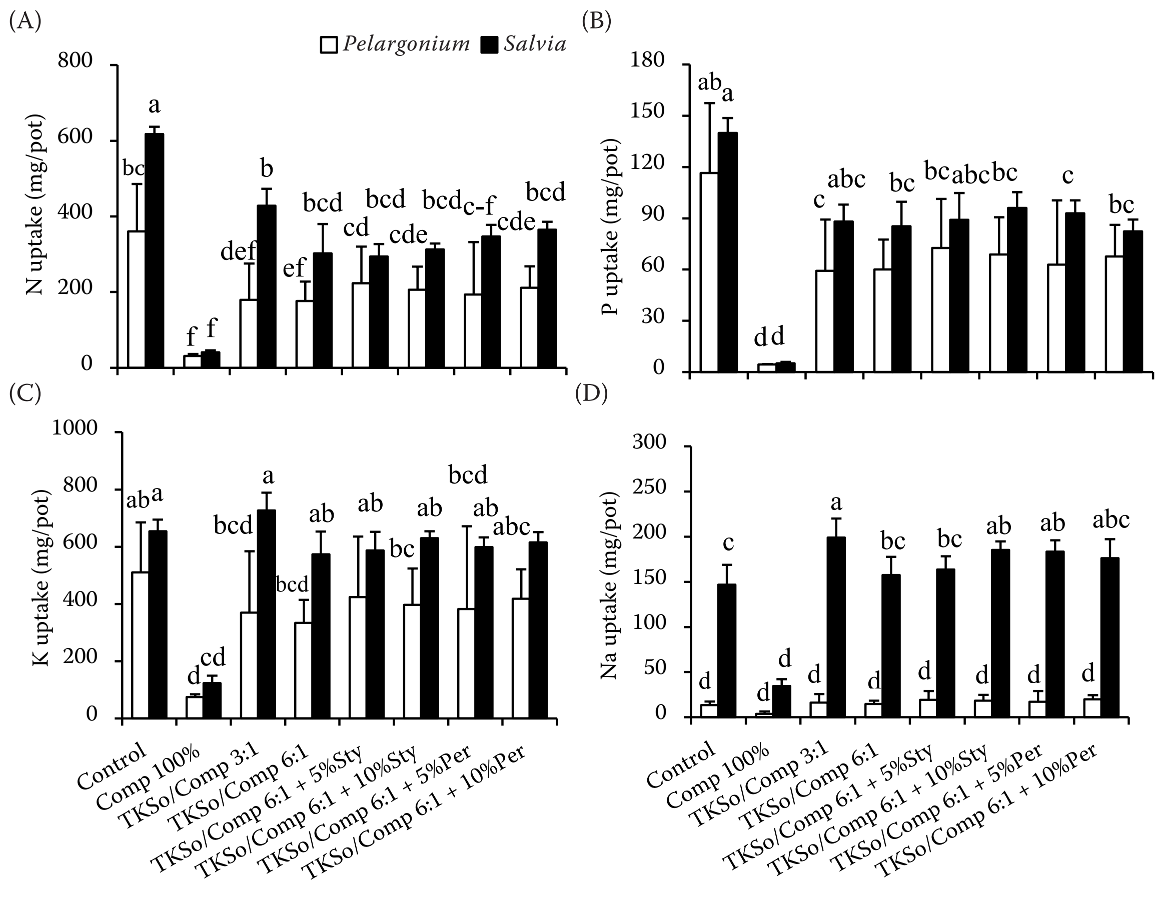

Figure 4. (A) Total N uptake; (B) total P uptake; (C) total K uptake and (D) total Na uptake of *Pelargonium* and *Salvia* grown in peat-based substrates. Comp – compost; TKS0 – standard soils; Sty – Styromull; Per – Perlite. For more details see Figure 1

and confirm that the supplement of additives to compost or peat-based potting substrates practically had unclear effects on plant growth and nutrient uptake. Therefore, these additives may also not be recommended as additives to peat-based substrates but they might be suggested in concern of peat substitution and reducing the dependence on peat.

In experiment 2, compost had more or less a role as fertilizer while TKS_0 was used as the main substrate diluting salt content and balancing available nutrients close to the levels of the standard soil, which enhanced total nutrient uptake of plants significantly. Additionally, the addition of 14–25% volume of compost to these peat-based media obviously favored plant growth, especially of more-salt sensitive plants like *Salvia*. This was further reported by Lamanna et al. (1991) for most of the ten studied ornmental plants grown in all mixtures of compost and peat as well as reducing peat volume to 25% compost by volume which was considered as a standard substrate having better plant quality than singular peat or compost.

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