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Characterization of beekeeping wastes for using in seedling production

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Abstract

In the present work, different strategies for the utilization of an organic beekeeping waste called «slumgum» were analysed. Slumgum appears in the beeswax-rendering process. A physico-chemical characterization was carried out and the hypothesis that slumgum could be used as nutrient source and growth substrate constituent for seedling production was tested. Analyses revealed that slumgum has an important potential for fertilization: 6.10% N, 0.23% P and 0.4% K, with a total organic matter average content of 78.63%. Also, some disadvantages such as an overly acid pH and high electrical conductivity were found. Assays of seedling production were carried out for two years and lettuce and pepper were used as model crops. Treatments were performed mixing different slumgum formats [minced slumgum (MS), slumgum-gypsum granules (SG) and slumgum-superphosphate granules (SC)] with peat (Pe): 25MS-75Pe (in %), 33MS-67Pe, 25SG-75Pe, 33SG-67Pe, 25SC-75Pe and 33SC-67Pe. Controls were no fertilized peat, organic and mineral commercial fertilizers. The best results for lettuce and pepper leaf area, shoot dry weight, and N percentage in leaf were obtained when treatment 25MS-75Pe was applied. Moreover for treatments 25SG-75Pe, no significant differences were observed with respect to the controls in seedbed parameters. Important reductions in emergence and seedling production were detected with SC, most probably due to their high acidity. Results suggest that MS (25MS-75Pe and 33MS-67Pe) and 25SG-75Pe offer a relevant nutritional potential and their high organic matter contents allow them to be considered as organic fertilizers.

Additional key words: compost, fertilizer, granulation, organic matter, organic residues, slumgum.

Resumen

Caracterización de residuos de industrias apícolas para su utilización en la producción de planteles

En este trabajo se analizaron diferentes estrategias para la utilización de un residuo orgánico de la industria apícola llamado «carozo», que se obtiene del proceso de extracción de cera. Se realizó una caracterización físico-química del residuo y se contrastó la hipótesis de que podría utilizarse como fuente de nutrientes y constituyente de sustratos para la producción de planteles hortícolas. Los análisis revelaron un importante potencial como fertilizante: 6,10% nitrógeno, 0,23% fósforo y 0,42% potasio, con contenido medio en materia orgánica del 78,63%. No obstante, presentó como inconvenientes un pH ácido y elevada conductividad eléctrica. Se realizaron, durante dos años, ensayos de producción de plantel eligiendo lechuga y pimiento como modelos. Los tratamientos fueron formulados mezclando distintos formatos de carozo [carozo picado (MS), gránulos yeso-carozo (SG) y gránulos superfosfato-carozo (SC)] con turba (Pe): 25MS-75Pe (en %), 33MS-67Pe, 25SG-75Pe, 33SG-67Pe, 25SC-75Pe y 33SC-67Pe. Los controles fueron turba sin fertilizar y dos fertilizantes, orgánico y mineral, comerciales. Los mejores resultados en ambos cultivos para área foliar, peso seco de parte aérea y porcentaje de nitrógeno en hoja, fueron obtenidos con 25MS-75Pe. No se observaron diferencias significativas en parámetros de semillero entre los tratamientos 25SG-75Pe y los controles. En los tratamientos con gránulos SC fueron detectadas importantes reducciones del porcentaje de emergencia y producción de plantel, debido probablemente a su alta acidez. Los resultados sugieren que los tratamientos con MS (25MS-75Pe y 33MS-67Pe) y 25SG-75Pe presentan un potencial nutricional importante y sus elevados contenidos en materia orgánica hacen que puedan ser considerados fertilizantes orgánicos.

Palabras clave adicionales: carozo, compost, fertilización, granulación, materia orgánica, residuos orgánicos.

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Introduction

The spectrum of agro-industrial wastes is very broad and a huge number of such materials can be used satisfactorily in agricultural production. A database with more than 100 of such materials together with their physical and chemical properties can be found in Abad *et al*. (2001). Many studies have attempted to assess the potential of different organic wastes as growing media and organic fertilizers (Zheljazkov *et al*., 2009). Many of them afford only good results when they are properly composted: biosolids, sewage sludge, green wastes, pruning wastes, olive-mill wastes, etc. (Murillo *et al.*, 1995; García-Gómez *et al.*, 2002; Bertrán *et al*., 2004; Papafotiou *et al.*, 2004; Benito *et al.*, 2005; Iñiguez, 2005; Urrestarazu *et al*., 2005; Zaller, 2007). In recent years, interest in other types of residues has increased due to the high costs of mineral fertilizers. Although the fertilizing properties of organic wastes are widely accepted, several limitations restrict their direct use in cropping systems. Some involve problems associated with phytotoxicity, runoff that affects water and soil quality, uncertain nutrient compositions, and high costs of transportation and handling (Burés, 1997).

In the nursery industry, peat has been used for many years as the main component in potting media. In order to satisfy environmental concerns, potential alternatives have been investigated for use as peat substitutes in nursery production systems (Zaller, 2007).

In this study, an organic waste called slumgum, produced in beekeeping industries, was studied. It appears in the beeswax-rendering process from old scraped honeycombs, which are eliminated every three or four years. This waste is dark (brown-black) in colour and is mainly composed of brood cocoons, moths and larvae of *Galleria melonella* L., dead bees, excrement, pollen, propolis, and small proportions of non-extractable wax. Although it is known that growers in beekeeping areas apply slumgum to the cropland to improve yields, no studies about the agronomic use of this material have been found in the literature. Considering a yield in the wax rendering process of 40% and a world wax production of 37,000 t (FAOSTAT, 2009), the worldwide slumgum production can be estimated at 55,500 t.

The aim of this work was to determine the main physico-chemical characteristics of slumgum waste and to test the fertilizing potential of slumgum in the nursery production of lettuce and pepper seedlings exploring the appropriated conditions for its use.

Material and methods

The slumgum used in this work came from the «Apícolas Fernández» beekeeping enterprise located (40° 54’ 6” N, 5° 39’ 54” W) close to Salamanca (Spain). The waste was first composted in piles at the factory. The composting process lasted 180 days and 20 samples were collected from the piles at different points. The slumgum samples were mixed and minced in order to reduce particle size (2-5 mm) and to avoid problems of both compacting and heterogeneity of the residue. In order to be used as fertilizers and growth medium constituent three different formats of slumgum were formulated: minced slumgum (MS), granules obtained by mixing slumgum with gypsum (SG) at a proportion of 1:1 (w/w), and granules prepared with slumgum and calcium superphosphate (SC) at a proportion of 1:0.5 (w/w), respectively.

Physico-chemical characterization of minced slumgum and granules

Parameters were studied following the methods indicated by Aendekerk *et al.* (2000) and the guidelines of the 824/2005 Spanish Royal Decree (BOE, 2005), concerning fertilizer products.

Six samples of slumgum and type of granule were analyzed for each parameter and their means were calculated. The parameters analyzed were as follows: 1) moisture content (M): samples were dried at 75° for 24 hours; 2) pH: sample/water, 1:2.5; 3) total organic matter (OM): estimation of ash weight after treatment in an oven at 550°C for 6 hours; 4) bulk density (BD): determined with a 100 cm^3 cylinder (Blake and Hartge, 1986); 5) electrical conductivity (EC): in saturated paste; 6) cationic exchange capacity (CEC): with the ammonium acetate method; 7) C-to-N ratio; 8) total

Abbreviations used: BD (bulk density), CEC (cationic exchange capacity), EC (electrical conductivity), F (fertilent®-mineral fertilizer), FFP (fertilizer-free peat), G (guano-organic fertilizer), M (moisture content), I (12 days after sowing), II (in the middle of the assays), III (at the end of the assays), L (length), MS (minced slumgum), OM (total organic matter), Pe (peat), SC (mixed slumgum with calcium superphosphate), SG (mixed slumgum with gypsum), W (width).

carbon (C) and sulphur (S): with a LECO CNS-2000 device; 9) total nitrogen (N): Kjeldahl method; 10) total phosphorus (P): Bray method; 11) total potassium (K): ammonium acetate method; 12) total calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn): by acid digestion (nitric, hydrochloric, hydrofluoric and boric acids) and atomic absorption spectrometry determination; 13) assimilable boron (B): by spectrophotometry using $\lambda = 420$ nm.

Experimental design and plant growth conditions

Seedbeds were established for lettuce (*Lactuca sativa* L. cv. Attractie) and pepper (*Capsicum annuum* L. cv. California) in order to obtain lettuce and pepper seedlings. Two assays were carried out during the years 2006 and 2007.

Six treatments using different substrates based on slumgum were studied. They were performed using minced slumgum (MS), granules obtained by mixing slumgum with gypsum (SG) and granules prepared with slumgum and calcium superphosphate (SC) in different proportions (w/w) mixed with a commercial peat (Pe). The proportions mixed with peat (in %) were: 25MS-75Pe, 33MS-67Pe, 25SG-75Pe, 33SG-67Pe, 25SC-75Pe and 33SC-67Pe. Two commercial fertilizers were employed as controls: organic fertilizer-guano (G) (Compo® Agricultura S.L., Barcelona, Spain; average nutrient concentrations: 11% N, 4% P_2O_5, 8% K_2O, 2% MgO, plus microelements) and mineral fertilizer-Fertilent® (F) (Mirat S.A., Salamanca, Spain; average nutrient concentrations: 20% N, 6% P_2O_5, 11% K_2O, 2% MgO, 20% SO_3). Proportions of these controls plus peat (in %) were 5G-95Pe and 2F-98Pe. A fertilizer-free treatment based of 100% peat (FFP) was also carried out as control.

The peat characteristics were: pH 6.0, 110 mg L^{-1} N, 130 mg L^{-1} P_2O_5, 180 mg L^{-1} K_2O, 60% OM, 1.25 dS m^{-1} EC (Gramoflor GmbH & Co. KG, Vechta, Germany).

Furthermore, at the beginning of the essays, physico-chemical analysis for substrate mixtures made with slumgum, granules and peat, corresponding to the different treatments, were also considered.

Seedlings were established using a randomized arrangement in trays with 28 cell plugs of 80 cm^3. Two seeds per cell plug were sown and only one plant per cell plug was left when these had developed one true leaf. The experiments were conducted in a greenhouse and were terminated when the plants had five true leaves. Lettuce seedlings were grown for 48 days in both 2006 and 2007. Pepper seedlings were grown for 70 days and 89 days in 2006 and 2007, respectively. The lettuce and pepper plants were watered by means of a subirrigation system following the FFP control necessities. No pesticides were applied.

Parameters recorded

The parameters recorded were: plant emergence percentage, number of leaves in the different growth stages, and —at the end of the assays— leaf area of the third one, root and shoot dry weight, leaf nitrogen content. These parameters were evaluated on all the 28 plants in each treatment. The number of leaves was counted 12 days after sowing (I), at the middle date (II) and at the end (III) of the assays. The leaves were numbered from the first leaf that emerged after the cotyledons to the last one. Leaf area was estimated using the formula $\pi LW/4$, L being length and W width. Plants were dried at 60°C for 72 hours and weighed on an electronic balance (A&D-ER-120A). Leaf nitrogen contents were determined in dry leaves with a LECO CNS-2000 device.

The differences between treatments were determined using analysis of variance (ANOVA). When significant differences ($p < 0.05$) among the treatments were observed, Duncan's multiple range test ($p < 0.05$) was determined. The Statgraphics-Plus 5.0 program was used for the calculations.

Results

Physical, chemical and nutrient composition of slumgum, granules and substrates

The results (in means) of the physical and chemical analyses of slumgum and their granules are summarized in Table 1. Moisture (%) varied from 3.07-5.27% in slumgum and granules. The pH values were quite acid and varied from 3.39 to 4.92. In all cases organic matter values were very high, ranging between 52.67 to 78.63%. The lowest bulk density corresponded to MS (0.3 g cm^{-3}), while the values obtained for the granules were around 0.5 g cm^{-3}. Electrical conductivity

Table 1. Physical, chemical and nutrient composition of slumgum and granules

	MS	SG	SC
M (%)	5.00	3.07	5.27
pH	4.92	4.74	3.39
OM (%)	78.63	52.67	67.23
BD (g cm^{-3})	0.30	0.54	0.55
EC (dS m^{-1})	8.90	9.30	13.70
CEC (cmol kg^{-1})	51.49	21.74	38.49
C/N	8.07	9.60	10.06
C (%)	49.00	29.60	39.30
N (%)	6.10	3.10	3.90
P (%)	0.25	0.15	2.32
K (%)	0.43	0.28	0.12
S (mg kg^{-1})	3,010	72,700	68,340
Ca (mg kg^{-1})	2,578	103,690	120,350
Mg (mg kg^{-1})	874	4,910	1,020
Cu (mg kg^{-1})	40	—	—
Fe (mg kg^{-1})	977	3,400	1,960
Mn (mg kg^{-1})	122	100	50
Zn (mg kg^{-1})	251	130	160
B (mg kg^{-1})	186	108	181

MS: minced slumgum. SG: granules of slumgum/gypsum. SC: granules of slumgum/calcium superphosphate. M: moisture. OM: organic matter. BD: bulk density. EC: electrical conductivity. CEC: cationic exchange capacity. —: not detected.

was quite high in all cases (8.9-13.7 dS m^{-1}). The cationic exchange capacity of these residues was high, obtaining the highest value (51.49 cmol kg^{-1}) in slumgum and the lowest (21.74 cmol kg^{-1}) in the SG granules. The C-to-N ratio ranged between 8.07 and 10.06. The N percentage was fairly high and ranged from 6% in MS to 3% in the SG granules. High P and K contents were recorded in both slumgum and granules.

The S, Ca values were higher in granules than in slumgum because of blending. The Mg contents were higher than those of the organic fertilizers. In general, the micronutrient content was suitable for plant nutrition.

The results of the physical and chemical analyses of substrates used in plant essays are summarized in Table 2. Moisture (%) varied from 30.76% to 35.07%. The pH figures ranged between 5.08 for 33SC-67Pe and 5.73 for 25MS-75Pe. Organic matter values were around 60% for all mixtures. Bulk density was reduced to values between 0.18 and 0.28 g cm^{-3}. Electrical conductivity values were too high and ranged between 3.16 to 5.46 dS m^{-1} in 25MS-75Pe and 33SC-67Pe respectively. The CEC was higher than 72 cmol kg^{-1} in all the substrates. The C-to-N ratio ranged between 16.35 and 33.82. Primary elements contents were reduced with respect to the slumgum and granules. For

Table 2. Physical, chemical and nutrient composition of mixtures (in % w/w) whit peat of slumgum and granules.

	25MS-75Pe	33MS-67Pe	25SG-75Pe	33SG-67Pe	25SC-75Pe	33SC-67Pe
M (%)	35.01	31.23	34.52	30.76	35.07	31.49
pH	5.73	5.61	5.68	5.52	5.30	5.08
OM (%)	64.66	64.52	58.17	56.98	61.81	61.78
BD (g cm^{-3})	0.18	0.23	0.24	0.28	0.25	0.28
EC (dS m^{-1})	3.16	3.74	3.26	3.89	4.36	5.46
CEC (cmol kg^{-1})	86.48	80.02	79.02	71.93	83.21	77.46
C/N	24.09	16.35	27.68	29.26	33.82	26.33
C (%)	38.79	38.59	32.57	31.90	35.85	35.81
N (%)	1.61	2.36	0.85	1.09	1.06	1.36
P (%)	0.13	0.17	0.07	0.10	0.87	1.15
K (%)	0.27	0.35	0.13	0.18	0.06	0.08
S (mg kg^{-1})	2,325	2,559	19,670	25,491	18,750	24,052
Ca (mg kg^{-1})	12,930	11,665	37,222	44,218	41,388	49,682
Mg (mg kg^{-1})	1,224	1,173	2,221	2,505	1,260	1,220
Cu (mg kg^{-1})	—	—	—	—	—	—
Fe (mg kg^{-1})	915	912	1,520	1,712	1,160	1,236
Mn (mg kg^{-1})	105	110	93	99	80	82
Zn (mg kg^{-1})	145	156	115	116	108	119
B (mg kg^{-1})	136	140	116	114	134	137

MS: minced slumgum. Pe: peat. SG: granules of slumgum/gypsum. SC: granules of slumgum/calcium superphosphate. M: moisture. OM: organic matter. BD: bulk density. EC: electrical conductivity. CEC: cationic exchange capacity. —: not detected.

instance, the highest N percentage was 2.36% recorded with the 33MS-67Pe mixture. Micronutrient substrate composition was quite similar for all mixtures.

Seedling production assays

The results of seedling production assays for lettuce and pepper are shown in Table 3. With respect to the plant emergence percentage, the 33SC-67Pe treatment afforded values of 56.25% and 40.17% for lettuce and pepper, respectively. In the 25SC-75Pe treatment values of 57.14% for lettuce and 55.35% for pepper were recorded. These results indicate that SC addition significantly reduced plant emergence as compared with the controls. No significant differences were found among the other treatments.

With regard to the number of leaves, date III, in both crops, all treatments afforded similar results except those performed with the SC granules, which yielded significantly lower numbers of leaves.

Leaf area ranged from 24.20 to 31.80 cm^2 in lettuce and from 7.73 to 18.46 cm^2 in pepper. The best results of both lettuce and pepper leaf areas were found when MS were applied generally in 25% proportion (w/w) with peat.

ANOVA analysis for shoot dry weight revealed significant differences among the treatments being the highest values 0.34 g in lettuce and 0.33 g in pepper. These results were again obtained when the 25MS-75Pe treatment was applied. No significant differences were found between 25MS-75Pe and 33MS-67Pe treatments.

In general, the highest values of root dry weight in lettuce and pepper were recorded with controls and MS (25MS-75Pe and 33MS-67Pe) treatments. Also, 25SG-75Pe treatment obtained similar values than controls for pepper dry weight.

Furthermore, MS addition increased the N leaf content, most probably due to the mineralization from the MS treatments. Values of 3.52% and 2.84% N leaf were obtained with the 25MS-75Pe treatment in lettuce and pepper, respectively. SG treatments showed higher N leaf content than controls for lettuce.

Organic and mineral fertilized controls did not improve seedling parameters with respect to the non fertilized peat control. Moreover no significant differences for both lettuce and pepper were observed between

Table 3. Mean results of plant parameters studied for lettuce and pepper seedbeds

	Controls			Treatment					
	FFP	**G (5%)**	**F (2%)**	**25MS-75Pe**	**33MS-67Pe**	**25SG-75Pe**	**33SG-67Pe**	**25SC-75Pe**	**33SC-67Pe**
Lettuce									
Plant emergence (%)	93.75[a]	92.13[a]	93.21[a]	91.17[a]	90.04[b]	90.18[a]	91.96[a]	57.14[b]	56.25[b]
Number of leaves I	2.00[a]	1.90[a]	2.10[a]	1.70[a]	1.60[a]	1.70[a]	1.90[a]	0.60[b]	0.80[b]
Number of leaves II	3.60[a]	3.60[a]	3.80[a]	3.10[a]	3.40[a]	3.10[a]	3.10[a]	1.50[b]	1.80[b]
Number of leaves III	5.00[a]	5.10[a]	5.20[a]	5.10[a]	5.00[a]	4.30[ab]	4.20[ab]	2.90[c]	3.20[bc]
Leaf area (cm^2)	24.80[b]	25.35[b]	29.68[a]	31.80[a]	30.02[a]	25.70[b]	24.90[b]	24.20[b]	25.20[b]
Dry weight root (g)	0.07[a]	0.06[a]	0.07[a]	0.07[a]	0.06[a]	0.06[b]	0.05[b]	0.01[c]	0.01[c]
Dry weight shoot (g)	0.22[b]	0.21[b]	0.24[b]	0.34[a]	0.32[a]	0.20[b]	0.16[c]	0.09[d]	0.08[d]
Leaf N (%)	2.41[c]	2.54[c]	2.56[c]	3.52[a]	3.32[a]	3.42[a]	3.23[b]	2.87[b]	3.06[b]
Pepper									
Plant emergence (%)	89.28[a]	85.62[a]	88.79[a]	73.21[a]	66.01[ab]	83.05[a]	74.10[a]	55.35[b]	40.17[b]
Number of leaves I	1.80[a]	2.00[a]	1.80[a]	1.50[ab]	1.35[b]	1.90[a]	1.70[a]	1.10[b]	1.15[b]
Number of leaves II	3.20[a]	3.30[a]	3.10[a]	3.30[a]	3.10[a]	3.40[a]	3.10[a]	2.60[b]	2.90[ab]
Number of leaves III	5.70[a]	5.80[a]	5.50[a]	5.60[a]	5.50[a]	5.70[a]	5.00[a]	4.20[b]	4.40[b]
Leaf area (cm^2)	15.62[b]	16.04[b]	15.80[b]	18.46[a]	18.21[a]	13.08[bc]	10.81[c]	7.73[d]	8.04[d]
Dry weight root (g)	0.14[ab]	0.15[ab]	0.14[ab]	0.19[a]	0.18[a]	0.15[ab]	0.13[b]	0.05[c]	0.06[c]
Dry weight shoot (g)	0.22[b]	0.22[b]	0.22[b]	0.33[a]	0.27[ab]	0.22[b]	0.16[c]	0.06[d]	0.09[d]
Leaf N (%)	2.64[b]	2.65[b]	2.67[b]	2.84[a]	2.78[a]	2.64[b]	2.66[b]	2.47[d]	2.53[c]

FFP: free-fertilizer peat control. G: Guano control. F: Fertilent® control. MS: minced slumgum. Pe: peat. SG: granules of slumgum/gypsum. SC: granules of slumgum/calcium superphosphate. [a-d] Letters indicate the statistically significant differences. Numbers I-III represent the times at which the leaves were counted.

25SG-75Pe treatment and controls but important delays were shown with 33SG-67Pe proportion. The treatments with SC granules significantly reduced growth with respect to the controls.

Discussion

Despite slumgum and granules have an interesting composition to be used as nutrient source for plants, the results also showed unsuitable EC levels for using as main component of substrates. An important reduction in EC levels was observed upon mixing with peat, but these values were still too high in the proportions evaluated (25% and 33% w/w) according with Abad *et al*. (2001) who considered that EC level should be less than or equal to 0.5 dS m^{-1} for the container media. Problems related to high EC levels were also described by Ehaliotis *et al.* (2005) for mushroom substrate and sheep manure. Komilis and Tsiouvaras (2009) found EC values in commercial compost of 6.46 dS m^{-1} and 8.52 dS m^{-1} produced from cow and poultry manure respectively. Notwithstanding the high values of EC in 25MS-75Pe and 33MS-67Pe treatments, the results obtained for lettuce and pepper seedlings can be positively considered.

Following the International Substrate Manual (Aendekerk *et al.*, 2000) the optimum pH values of the materials for the container media should be between 5.3 and 6.5. The pH values after slumgum residues had been mixed with peat got between these levels, except those made with SC granules.

The moisture percentages can allow a suitable both management and storage (López-Mosquera *et al*., 2003). The bulk density of slumgum (< 0.4 g cm^{-3}) is considered optimum for substrates (Abad *et al*., 2001). In this study, the bulk density values increased with residue granulation, which could make it possible a better distribution of granulated forms. Both materials (slumgum and granules) can be considered organic fertilizers because the reference value (40% OM) was exceeded in all cases (Danés and Boixadera, 2001). Accordingly, these materials could be used to improve the physical conditions of soils.

The CEC was strongly affected by the amount of OM (correlation coefficient, 0.93) and values were increased when mixtures with peat were carried out. Sahin *et al.* (2002) also observed a high correlation between the OM and the CEC in peat and sawdust. At the experiment time all the materials were stabilized, since the C-to-N ratio was equal or lower than 10. The material can be considered, in this case, as mature compost, with all the benefits that this would bring to crop production (Bertran *et al*., 2004).

Nitrogen is considered to be the most important nutrient present in slumgum. The percentage of this element was quite high in all the materials and ranged from 6.10% in MS to 3.10% in the SG granules. These values were reduced by around 1% when the mixtures with peat were performed. Analysing different types of vermicompost, Giulietti *et al*. (2008) reported values ranging from 0.029 to 1.23% and, in another experiment, Badr El-Din *et al.* (2000) obtained values of 0.82% in sugar beet haulms. The N ratios of the materials analysed in this study were higher than those of the most common organic fertilizers (Burés, 1997). These values allow slumgum and its derived granules to be considered interesting alternatives to be considered for fertilizers.

Moreover, P contents also showed important ratios (0.21-0.31%). These were higher than those recorded for other common organic fertilizers (Papafotiou *et al*., 2004). With respect to the K level, the value obtained for slumgum (0.42%) was similar to those recorded for vermicompost (Zaller, 2007).

Regarding Ca, Mg and S elements, the values in the different materials and mixtures with peat were suitable for the needs of the growing plants. The micronutrients contents were also quantitatively important in all cases. It should be noted that neither of these values was within the contaminant range provided for by Spanish legislation concerning fertilizer products (BOE, 2005).

According to the seedling production assays, the SC (25SC-75Pe and 33SC-67Pe) treatments reduced the emergence of lettuce and pepper seedlings by 35% with respect to the controls. This inhibitory effect on growth was possibly associated to the high acidity (pH 5.30 and 5.08 respectively). Stoffella *et al.* (1997) also found important reductions in seedling emergence when different composts were applied in green pepper production. In contrast, the mixtures with MS (25MS-75Pe and 33MS-67Pe) and SG (25SG-75Pe and 33SG-67Pe) granules afforded similar plant emergence percentages to those found in the controls.

Treatments with the SC granules also afforded a significantly lower number of leaves than all the other treatments. The delay was observed throughout plant growth. This negative effect on plant development could be explained in terms of the high EC and acid pH. At the end of the lettuce assays, the best results with respect to the number of leaves were obtained with the controls and with the MS (25MS-75Pe and 33MS-67Pe) treatments, which afforded a mean of 5 leaves per plant. In pepper, at the beginning of the assays the lowest numbers of leaves were recorded in substrate fertilized with the SC (25SC-75Pe and 33SC-67Pe) and MS (25MS-75Pe and 33MS-67Pe) treatments. However, the MS (25MS-75Pe and 33MS-67Pe) treatments considerably increased the number of leaves in the middle and at the end of the assays. This result suggests that MS addition produced in pepper a delay in the first growth phases, which was compensated at the end of the assays, producing high-quality seedlings (with the highest figures for dry matter). The increased growth was probably due to the reduction in EC during the culture period due to soluble salt leaching (Papafotiou *et al.*, 2001).

Regarding leaf area both lettuce and pepper showed the best results when 25MS-75Pe was used.

The root growth of lettuce and pepper plants fertilized with SC granules was appreciably reduced. This again suggests that growth inhibition might be due to the high acidity and electrical conductivity of the SC granules. In contrast, the highest figures for shoot dry weight were obtained with 25MS-75Pe as fertilizer. This indicates that the nitrogen supplied by slumgum would be suitable for plant growth. Thus, slumgum could be a source of nutrients even when no chemical fertilizers are used.

The fact that organic and mineral fertilized controls did not improve seedling parameters with respect to the unamended control might be explained by both a poor solubility of mineral elements in guano and a very slow liberation in Fertilent®.

Moreover, in both crops no significant differences at the 95% confidence level were observed in the shoot and root dry weights between the controls and plants treated with the 25SG-75Pe. However, the treatments with 33SG-67Pe and the SC granules (25SC-75Pe and 33SC-67Pe) reduced lettuce and pepper aerial and root growth with respect to the controls.

Thus, SG granules mixed in high proportions with substrate should not be used in crop production because of the leaching of soluble salts would be difficult in a granule performance with high EC (9.30 dS m^{-1}).

Although, in general, no significant differences were found between 33MS-67Pe and 25MS-75Pe treatments, the best mean values for both lettuce and pepper seedling parameters were obtained in 25MS-75Pe ratio with peat. Hence, it could indicate a better growing media for this treatment, most probably due to greater values of EC in 33MS-67Pe treatment.

In general, with addition of MS both lettuce and pepper crops presented the best results for seedling parameters, even increasing those obtained with commercial fertilizers controls. Our results suggested that, 25 and 33% proportion with peat of MS had a positive influence in seedling quality, obtaining the best values for leaf area, dry weight and leaf N content.

As conclusions, physico-chemical analyses of slumgum-waste revealed very high values of organic matter (78.63%) and a medium content of primary fertilizer elements of 6.10% N, 0.23% P and 0.42% K. Although further studies are needed to explore the possibilities of a standardized use of slumgum, the results of this study suggest that slumgum-peat mixtures could reduce peat consumption, affording also a use for this residue. Minced slumgum and granules slumgum/gypsum present a suitable composition in order to be used as fertilizers and growing medium constituent. Substrates based on minced slumgum mixed with peat (25MS-75Pe and 33MS-67Pe) appear to be very interesting materials for lettuce and pepper seedling production. Future studies to be carried out at Vegetable Production Area of Salamanca University will examine the possibilities of its use in other crops such as flowers or ornamental potted plants.

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