ACTA Acta Sci. Pol. Hortorum Cultus, 16(3) 2017, 85–95

www.acta.media.pl ISSN 1644-0692 DOI: 10.24326/asphc.2017.3.9

ORIGINAL PAPER

Accepted: 12.01.2017

MINERAL COMPOSITION AND QUALITY PARAMETERS OF GREENHOUSE-GROWN LETTUCE (*Lactuca sativa* L.) DEPENDING ON FERTILIZATION WITH AGRICULTURAL WASTE COMPOSTS

İlker Sönmez[1]✉, Hüseyin Kalkan[1], Halil Demir[2], Recep Külcü[3], Osman Yaldiz[4], Mustafa Kaplan[1]

[1] Department of Plant Nutrition and Soil Science, Faculty of Agriculture, Akdeniz University 07058, Antalya, Turkey

[2] Department of Horticulture, Faculty of Agriculture, Akdeniz University 07058, Antalya, Turkey

[3] Department of Agricultural Machinery and Technology Engineering, Faculty of Agriculture, Süleyman Demirel University 32260, Isparta, Turkey

[4] Department of Agricultural Machinery and Technology Engineering, Faculty of Agriculture, Akdeniz University 07058, Antalya, Turkey

ABSTRACT

Agricultural wastes have increased with the intensive production in recent years. These wastes that affect the physical, chemical and biological properties of soils should be composted and added to soil. In this study, composts were consisted of different agricultural wastes such as greenhouse wastes-GPW, used cocopeat wastes-UCW, spent mushroom composts-SMC and at different ratios. Used cocopeat wastes were especially chosen in this experiment because it was not preferred in compost mixtures up to the present. Five different compost mixtures were added to the soil and their effects on growth and nutrient contents of lettuce plants were determined. The experiment was carried out during two successive seasons (autumn and spring). The results showed that plant growth and yield were found higher in the compost applications than in control. Generally the highest values were obtained from M1 application (80% GPW + 10% UCW + 10% SMC) for many parameters.

Key words: greenhouse plant wastes, used cocopeat wastes, spent mushroom compost, lettuce growth, yield, quality

INTRODUCTION

Agricultural wastes are rapidly increasing with population growth. In recent years, especially it has gained importance with the environmental trends began to increase utilization of waste. Organic wastes have traditionally been considered as a source of pollution and have not been sufficiently evaluated as a by-product of agricultural activity which could produce organic fertilizers by composting. Furthermore, due to the high cost of substrates and imported inputs, there is a need for stable and quality material produced locally [Kowalchuk et al. 1999, Rodríguez et al. 2008]. For this reason, agricultural wastes should be utilized in useful ways. An organic fertilizer can be obtained by ensuring recycling by means of composting that is one of the best utilization methods for organic wastes. Composting is the process where

✉ ilkersonmez@akdeniz.edu.tr

organic wastes are decomposed by microorganisms under aerobic conditions [Haug 1993]. In the composting process, microorganisms decompose the organic material and expose thermal energy. This thermal energy increases the temperature of the compost pile and inactivates the pathogen microorganisms [Epstein 1997, Rantala et al. 1999]. Therefore, it is of great importance to measure the temperature of the pile while carrying out the composting process. In composting, optimum C : N ratio should be 30 : 1, optimum humidity 30–60% and pH around 6.5–7.5 for microbial decomposition [Erdin 2016].

A part of greenhouse vegetable production is carried out by soilless culture methods and this production method has also been an increasing trend in recent years. Soilless agriculture is involving 750.7 ha in Turkey [http://www.byegm.gov.tr…] and using growing media as cocopeat, rockwool, perlite etc. Use of cocopeat in soilless culture vegetable production has increased in recent years and the amount of cocopeat waste tends to increase in parallel. It is estimated that an average of 10–14.5 t da^{-1} of cocopeat waste is produced every 2–3 years. Cocopeat wastes have a serious potential and these wastes must be evaluated by mixing the other materials.

In Turkey, vegetable production in greenhouse started in Antalya in 1940's and total protected areas which included high tunnel, low tunnel and greenhouses reached to 61 500 ha in 2013. The sum of vegetables grown in greenhouse areas in Turkey are made up of tomato (3 092 083 tons), cucumber (1 003 535 tons), eggplant (229 818 tons) and pepper (384 661 tons). Those four important greenhouse vegetables which have a substantial production potential constitute 78% of the greenhouse production in Antalya Region [http://www.tarim.gov.tr…]. With the increase in production of vegetables, an increase is also observed in the waste quantities. Anton et al. [2005] stated that the most important problem in greenhouse production was the produced wastes. Kaplan et al. [2001] pointed out that annually 57 500 and 330 625 tons of plant wastes from the tomato greenhouses were thrown in the environment randomly and eliminated by burning method in Kumluca and Antalya Regions respectively. Kürklü et al. [2004] reported that annual total amount of biomass waste produced from tomato and eggplant plants in the greenhouses were determined as 111 480 tons and 15 870 tons, respectively in Antalya.

Mushroom compost cannot be used for mushroom cultivation consistently after losing the desired properties by mushroom and is removed from the environment. Because of the rich and valuable organic matter content, spent mushroom compost can be evaluated in many different ways as indicated by different investigators [Danny 1992, Tüzel et al. 1992, Szmidt and Conway 1995]. Spent mushroom compost is usually used as growing media in floriculture and sometimes is randomly discarded.

Lettuce is grown in large quantities in the world and the most important producing countries of lettuce are China and the United States where 65% of the total production occurs. Turkey's lettuce production quantity is 436 785 tons for 2013 [http://www.tuik.gov.tr…].

In the present study, greenhouse plant waste combined with used cocopeat wastes and spent mushroom compost at different ratios was applied to pot soils, and the effects of these materials were investigated on lettuce yield, quality and nutrient contents.

MATERIALS AND METHODS

Greenhouse tomato plant wastes (GPW), used cocopeat wastes (UCW) and spent mushroom composts (SMC) were mixed at five different ratios based on dry material for composting (tab. 1). These mixtures were blended until they become homogeneous with mixer. Then, different mixtures prepared were placed into the composting system. Piles to be placed into the reactors were formed to contain 10 kg of dry material from each. Humidity of the piles were brought to 65–70% level which is the optimum level for composting process and been mixed until a homogenous mixture is obtained.

Composting process was carried out in the reactor-type composting system. Composting reactors were made up of plastic material insulated against heat transfer and had a volume of 127 liters. Ventilation inside the reactors was performed by 3-phase radial fans. Temperature was measured at three different points (top, mid and bottom) inside the reactors on a vertical axis passing through the central point (fig. 1). Composting process was performed under controlled conditions and composts were kept waiting for maturation phase at the end of the pre-composting process.

Table 1. The part of the agricultural wastes in compost mixtures (%)

Mixture	Greenhouse plant waste	Used cocopeat wastes	Spent mushroom compost
M1	80	10	10
M2	70	20	10
M3	60	30	10
M4	50	40	10
M5	55	40	5

Management and monitoring of the process in the composting system were carried out by the use of PLC-based (programmable logic controller) process control device. Flow rate of the air blown into the reactor by fans were measured by a flowmeter and the result of the measurement was conveyed to the PLC unit. By the use of ventilation value entered to the interface, PLC unit determines the optimum air flow rate and alters frequency to provide the optimum flow rate according to the data obtained from the flow meter. Frequency tuner adjusts the frequency of the electricity current conveyed to fans and enables them to perform ventilation at the adjusted flow rate level. Ventilation ratio was adjusted to 0.4 l/km$_{DOM}$ in the tests and ventilation period in these experiments was adjusted for 15 minutes in an hour [Külcü and Yaldız 2004]. PLC unit also measures the temperature of the piles. Temperatures of piles measured were recorded in every 15 minutes (fig. 2).

Chemical contents of composts taken from reactors at the end of the composting process were presented in Table 2. Five different composts (1 ton from each per ha^{-1}) were added to pot soil by taking humidity contents into account for production of lettuce and the pot experiment was carried out autumn (1st season) and spring (2nd season) successively. The soil used in the experiment was also chemically analyzed as a control and shown at Table 3.

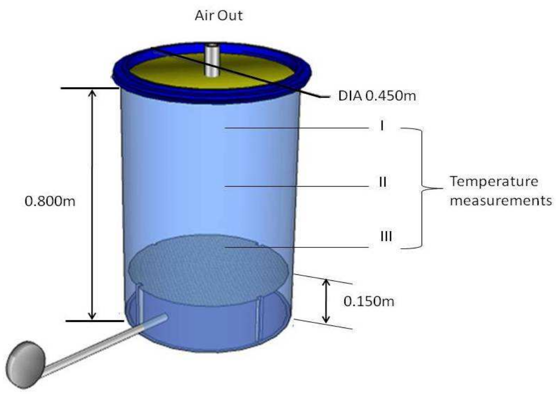

Fig. 1. Properties of container composting reactor

The pot experiments (10 kg pot^{-1}) were established as a randomized plot design with four replications and conducted under greenhouse conditions

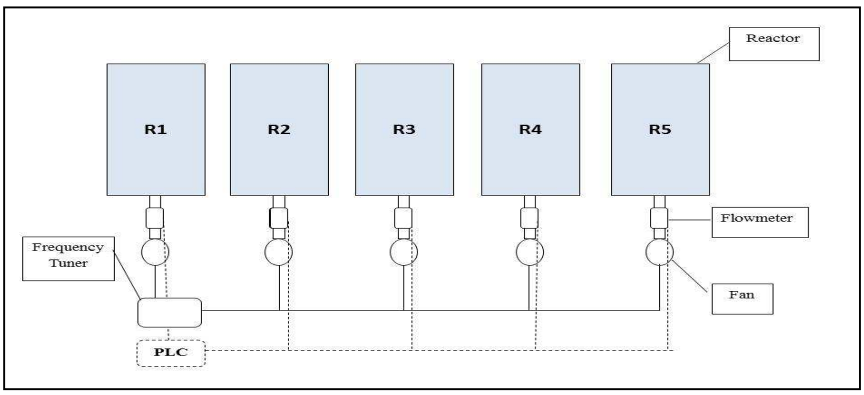

Fig. 2. The type of reactor composting system

Table 2. The chemical contents of compost samples

Mixture	pH	EC	N	P	K	Mg	Ca	Fe	Zn	Mn	Cu
		(dS m^{-1})			(%)				(mg kg^{-1})		
M1	7.87	11.87	1.87	1.99	2.86	0.56	4.24	9630	1433	3251	235
M2	7.60	11.80	1.88	1.89	2.70	0.51	3.76	7045	1114	1945	194
M3	7.50	8.32	1.56	1.70	2.02	0.49	3.79	7539	1191	2513	195
M4	7.17	7.70	1.52	1.63	1.72	0.47	3.32	6637	1098	2139	187
M5	7.46	8.87	1.59	1.86	2.06	0.46	3.22	6103	1005	1659	178

in which each pot was planted with lettuce plants (Bitez). All of the necessary culture processes were performed during the vegetation period and experiment was terminated by harvesting the plants.

All the plants in each pot were harvested and head height (cm), head diameter (mm), leaf number (per plant), total and marketable yield and leaf color values were determined. Fresh weight of the harvested plants was weighed, and then the leaves of lettuce were rinsed with distilled water after washing with tap water and blotted dry with paper towels and were dried in an air-forced oven at 65°C to constant weight. After drying dry weights were recorded. 0.5 g of each dried plant samples were digested with 10 mL $HNO_3/HClO_4$ (4 : 1) acid mixture on a hot plate and then the samples were heated until a clear solution was obtained. The same procedure was repeated for several times. Vitamin C was determined according to Pearson [1970]. Concentrations of K, Ca, Mg, Fe, Zn, Mn and Cu in the digestates were determined by using inductively coupled plasma (ICP) [Kacar and İnal 2008]. Phosphorus was measured by spectrophotometer [Kacar and Kovancı 1982] and N was determined by a modified Kjeldahl procedure [Kacar and İnal 2008]. L*, a* and b* values were measured by means of Minolta CR 400 color chroma meter at the outer leaves in lettuce. C (Chroma) and Hue (°) angle values were calculated by the determined a* and b* [Siomas et al. 2002, Madeira et al. 2003].

In composts, pH [DIN 11542:1978-01], nitrogen [Kacar 1972], phosphorus [Kacar and Kovancı 1982], and K, Ca, Mg, Fe, Zn, Mn and Cu [Kacar and İnal 2008] were determined by preferred analysis methods.

Table 3. The evaluate of mineral compounds in the soil

Parameters	Value
Total N (%)	0.069
P (mg kg^{-1})	20.2
K (mg kg^{-1})	105.7
Ca (mg kg^{-1})	2754
Mg (mg kg^{-1})	689.7
Fe (mg kg^{-1})	14.7
Zn (mg kg^{-1})	1.2
Mn (mg kg^{-1})	10.8
Cu (mg kg^{-1})	3.4

All data were subjected to analysis of variance and significance ($p < 0.05$) was detected for treatment effects, the least significant difference (Duncan) value calculated by 5% (MSTAT-C packet program).

RESULTS AND DISCUSSION

Plant growth and yield

The changes in the plant growth, physical-chemical properties and yield showed significant variation ($p < 0.05$–0.001) except for color values (L, Chroma and Hue) and compost applications increased with compared to control application. The effects of composts on the head height, head diameter, leaf number of the lettuce are presented in Table 4. Head height, head diameter, leaf number were measured as indicators of plant growth (tabs 4 and 5).

Table 4. The effects of different composts on head height, head diameter, leaf number of lettuce

Combinations	Head height (cm)		Head diameter (mm)		Leaf number (per plant)	
	autumn	spring	autumn	spring	autumn	spring
M1	20.5a	21.5a	20.74a	21.68a	42.0a	44.5a
M2	17.0b	18.5ab	13.23b	18.53ab	28.5b	42.0a
M3	16.3bc	17.3b	13.58b	16.62b	31.0b	41.3a
M4	15.3bc	17.5b	11.84bc	16.44b	27.3b	41.5a
M5	14.8c	16.3bc	10.57cd	16.22b	26.8b	42.8a
Control	12.0d	13.3c	9.17d	15.79b	26.0b	35.8b

Values are means (n = 4). Values in a row followed by different letters indicate significant differences ($p < 0.05$) between treatments according to a Duncan's multiple range test
Significance level: $p < 0.001$

Table 5. Effects of different composts on Vitamin C contents, marketable yield and total yield of lettuce

Combinations	Vitamin C (mg 100 g^{-1})		Marketable yield (g plant^{-1})		Total yield (g plant^{-1})	
	autumn	spring	autumn	spring	autumn	spring
M1	27.9b	34.5bc	321.0b	397.6a	342.9c	435.2a
M2	25.3c	45.7a	376.4a	333.3ab	403.4b	368.7b
M3	33.0a	33.1cd	387.1a	319.6b	408.5b	353.9b
M4	19.0d	31.7d	351.0ab	319.2b	370.3bc	350.9b
M5	19.7d	31.7d	365.5a	309.8b	487.3a	347.1b
Control	32.0a	35.2b	145.0c	153.5c	154.0d	160.9c

Values are means (n = 4). Values in a row followed by different letters indicate significant differences ($p < 0.05$) between treatments according to a Duncan's multiple range test
Significance level: $p < 0.001$

The head height values of lettuce were observed to increase with compost applications compare to control in both seasons. The maximum head height value was recorded from M1 mixture in both periods, while the minimum head height value was obtained in control. Similarly the highest values of head diameter and leaf number were obtained from M1 mixture in both periods, while the lowest value of head height was from control application. M1 mixture in the vegetative development of lettuce caused significant increases in many parameters. Alvarez et al. [1995] reported that plant growth significantly increased compared to control plants when compost was added to soil. Pimentel et al. [2008] observed a positive response on the heads diameter of the lettuce culture when they increased doses of organic compounds. Kütük et al. [1999] reported that spent mushroom compost and tea waste composts have important chemical and physical properties and can be used as an alternative to manure. The leaf numbers of lettuce varied significantly according to compost applications tested. The maximum leaf numbers of lettuce was recorded in M1 mixture in autumn, while maximum leaf numbers were obtained from all compost mixtures in spring. Manal et al. [2012] reported that compost added to soil increased leaf number of lettuce.

Vitamin C content was significantly influenced by the treatments in both seasons (tab. 5). The maximum Vitamin C content in autumn was shown in M3 combination, while the maximum Vitamin C content in spring was shown in M2 combination. The contents of Vitamin C in lettuce can be varied depends on different applications and Ismail and Fun [2003] determined that organically grown lettuce contains about 50 mg 100 g^{-1} Vitamin C. The effects of composts on marketable-total yield and leaf color values of the lettuce are presented in Tables 5 and 6. The results showed that there were significant differences in marketable and total yields among compost applications in autumn and spring ($p < 0.001$). Total and marketable yield with the compost applications increased significantly compared to control. Although the other compost mixtures increased significantly, the maximum yield values were obtained from M1, M2, M3 and M5 applications with regard to many parameters. Especially the decreases in spring are higher than the autumn in total and marketable yield values except for M1 and control applications (tab. 5). Compounds resulting from decomposition of the organic matter provide a positive contribution to the development of plants. Therefore, especially the maximum values were recorded in spring season. All compost applications (especially M1 and M3) have the highest values in terms of nutritional content and especially nitrogen which is effective in improvement and considered to be cause of high increase in productivity. Addition of soil organic matter raises the plant growth due to high nitrogen content and increases soil organic matter content by composing plant vegetation on soil [Akalan 1987, Haynes and Naidu 1998].

The maximum marketable yield values in autumn were recorded from M2, M3 and M5 applications and spring growing seasons were recorded in M1 application. The minimum marketable yields were recorded in control application in both seasons. Similarly the maximum total yield in autumn was recorded in M5 application and spring growing period was recorded in M1 application. The minimum total yield was determined in control application in both seasons. Sakara and Zhiltsov [2007] determined that the organic fertilizer increased yields in vegetables. Porto et al. [2008] used different levels of organic fertilization with lettuce and reported that yield was significantly higher in lettuce plants. Polat et al. [2004] stated that the lettuce growth was increased with the spent mushroom compost added to soil at different ratios and the best results in total and marketable yields were obtained from 2–4 t da^{-1} applications at different periods. Rooster [1999] used three different types of compost and showed the highest lettuce yields with using this compost. Tüzel et al. [2003] found that the highest cucumber total yield was recorded with chicken manure and farmyard manure treatments.

There was no statistically significant difference among the compost applications on color values of lettuce except for Hue values in autumn (tab. 6). The highest Hue value (119.17) was obtained from control application. In the spring growing period, all applications were included in the same group. The L and Chroma values did not vary significantly in both growing periods.

Table 6. Effects of different composts on L, Hue, Chroma values (color) of lettuce

Combinations	L		Hue		Chroma	
	autumn	spring	autumn	spring	autumn	spring
M1	57.35	45.95	116.51bc	124.44	47.74	33.24
M2	61.04	47.23	116.31bc	123.87	45.77	34.56
M3	53.49	46.91	118.74ab	123.97	43.23	32.58
M4	59.26	48.60	116.97abc	123.39	47.54	33.63
M5	59.70	49.60	115.55c	122.18	45.11	36.45
Control	52.85	46.44	119.17a	121.93	43.92	30.62
Significant levels	ns	ns	*	ns	ns	ns

Values are means ($n = 4$). Values in a row followed by different letters indicate significant differences ($p < 0.05$) between treatments according to a Duncan's multiple range test
Significance levels: * – $p < 0.05$; ns – not significant

Nutrient element contents

The effects of composts on the macro nutrient contents of the lettuce are presented in Table 7. The nitrogen, phosphorus, potassium, calcium, magnesium contents were found to be significant nutrient element contents in both periods except for K (autumn) and Ca (spring) contents and all compost applications of composts increased with comparing to control.

Statistical analysis of the data on nitrogen content of lettuce revealed significant differences among composts treatments in both periods. While the maximum nitrogen content in lettuce was obtained from M3 mixture in autumn, the maximum nitrogen contents were found from all compost applications in spring. The leaves of lettuce in control application had the minimum N contents compared with the compost applications in both periods. Vidigal et al. [1995] used farm yard manure at different levels during cultivation of lettuce and reported that N, P and K concentrations of leaf increased with rising compost rates except for Ca concentration. Brito et al. [2014] recorded that municipal waste compost applications increased the nitrogen, phosphorus and potassium accumulation in lettuce. Demir et al. [2003] found that the nutrient contents of lettuce were enough with the organic manure applications. Çalışkan et al. [2014] reported that the total N content of lettuce leaves in organic production systems was higher than in the conventional production system.

The phosphorus contents of lettuce with compost applications increased significantly compared to control in both autumn and spring vegetation period. The maximum phosphorus value in lettuce was obtained from M1 application in autumn season, but all applications were located in the same group in spring season. The minimum phosphorus contents of lettuce were obtained from control application in both periods. Especially M1 application played an important role in terms of phosphorus nutrition. The maximum potassium content of lettuce was detailed from M1 application in autumn, but the potassium content of lettuce in spring did not vary significantly. Organic fertilizers and soil enhancers are used for their organic matter contribution and nutrients, mainly N and P [Fuente et al. 2006]. The application of organic fertilizers in lettuce cause increases in production and nutrient content in plants [Rodrigues and Casali 1999].

Table 7. Effects of different composts on macronutrient contents of lettuce (%)

Combi-nations	N		P		K		Ca		Mg	
	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring
M1	2.37abc	3.08a	0.37a	0.35a	5.92a	4.63	1.27a	0.78	0.60a	0,37a
M2	2.25bc	3.18a	0.30bc	0.38a	3.95b	4.80	0.67bc	0.83	0.33cd	0,36a
M3	2.71a	3.09a	0.31bc	0.36a	4.44b	4.70	0.77b	0.72	0.37bcd	0,33a
M4	2.50ab	2.97a	0.29bc	0.36a	4.03b	4.49	0.83b	0.71	0.41b	0,35a
M5	2.09c	3.24a	0.33ab	0.36a	4.12b	4.75	0.74bc	0.83	0.38bc	0,39a
Control	1.98c	2.46b	0.25c	0.22b	3.70b	4.28	0.49c	0.77	0.30d	0,26b
Significant levels	***	*	***	***	***	ns	***	ns	***	***

Values are means (*n* = 4). Values in a row followed by different letters indicate significant differences ($p < 0.05$) between treatments according to a Duncan's multiple range test
Significance levels: * – $p < 0.05$; *** – $p < 0.001$; ns – not significant

Table 8. Effects of different composts on micronutrient contents of lettuce (mg kg^{-1})

Combi-nations	Fe		Mn		Zn		Cu	
	autumn	spring	autumn	spring	autumn	spring	autumn	spring
M1	109.00c	230.38	49.28	60.67	45.27b	75.96bc	5.57	6.51
M2	67.73c	344.53	50.20	68.74	45.98b	89.20ab	5.54	7.17
M3	77.95c	375.58	49.90	65.94	48.66b	58.81c	6.26	7.15
M4	152.80b	207.00	50.72	61.71	51.56b	75.06bc	6.12	6.55
M5	215.38a	337.30	47.71	67.27	53.53b	90.31ab	4.94	6.56
Control	72.18c	340.15	48.77	74.13	73.56a	108.08a	5.22	7.76
Significant levels	***	ns	ns	ns	**	**	ns	ns

Values are means (*n* = 4). Values in a row followed by different letters indicate significant differences ($p < 0.05$) between treatments according to a Duncan's multiple range test
Significance levels: ** – $p < 0.01$; *** – $p < 0.001$; ns – not significant

The maximum calcium and magnesium contents of lettuce were determined in M1 mixture in autumn season, while the lowest Ca and Mg values in autumn were obtained from control. The differences in Ca and Mg contents among the applications weren't found statistically significant in spring. Kaplan et al. [2008] achieved increases in the contents of Ca and Mg in lettuce with organic fertilizer applications. Hernandez et al. [2010] reported that the leaf content of Ca, Mg, and Mn showed higher values inorganic fertilization treatments.

The effects of composts on the micro nutrient contents of the lettuce are presented in Table 8. The iron (autumn season) and zinc contents of lettuce were found to be significant but the manganese and copper contents of lettuce did not vary statistically. The compost applications on lettuce growth caused to increase of micronutrient contents in spring seasons compare to autumn and it is estimated to be caused by decomposition of organic matter.

The maximum iron content of lettuce was obtained from M5 application in autumn season and the maximum zinc content was obtained from control application. The copper and manganese contents did not vary significantly in autumn and spring. Compost application to agricultural land may result in enhanced metal concentrations in soils as well as in a significant increase in plant growth. The metal concentrations depend on the application periodicity as well as on the amount of compost applied to the soil [Bauduin and Impens 1985, Abdel–Sabour and El–Seoud 1996]. Increased concentrations of trace elements and heavy metals have been often reported in the tissues of crops growing in soils amended with MSW-compost. Their accumulation on crops depends on numerous factors, including soil properties, plant species, compost application rate, and compost content in metals [Zheljazkov and Warman 2004, Smith 2009].

CONCLUSION

The results of study indicated that the effects of compost applications on plant growth, yield and the nutrient contents of lettuce were found significant and promoted the growth. The best results of plant growth, yield and the nutrient contents of lettuce were determined in the M1 application (80% GPW + 10% UCW + 10% SMC) and the lowest results were obtained in the control application. Composts derived from different organic materials, enhances plant growth and the nutrient contents. Therefore agricultural wastes must be composted and used in agricultural lands. Since the utilization of organic waste materials, waste materials will no longer be a problem and this will increase the amount of organic materials and fertility parameters that are useful for soil. The used cocopeat wastes are a new species waste and these waste amounts trends to increase. The used cocopeat wastes can be used as carbon source in compost mixtures because of high carbon level.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the Scientific Fund of Akdeniz University (Project no: 2010.01.0104.005)

REFERENCES

Abdel-Sabour, M.F., El-Seoud, M.A.A.A. (1996). Effects of organic-waste compost addition on sesame growth, yield and chemical composition, Agric. Ecosyst. Env., 60, 157–164.

Akalan, İ. (1987). The source of organic matter. Soil Science. Ankara Univ. Faculty of Agriculture Publications, 309, 218–219.

Alvarez, M.B., Gagne, S., Antoun, H. (1995). Effect of compost on rhizosphere microflora of the tomato and on the incidence of plant growth-promoting rhizobacteria. Appl. Env. Microbiol., 61, 194–199.

Anton, M.A., Munoz, P., Castells, F., Montero, J.I., Solvia, M. (2005). Improving waste management in protected horticulture. Agron. Sustain. Dev., 25, 447–453.

Bauduin, M.O., Impens, R. (1985). Agronomic valorization of municipal waste composts, Acta Hort., 172, 117–124.

Brito, L.M., Monteiro, J.M., Mourao, I., Coutinho, J. (2014). Organic lettuce growth and nutrient uptake response to lime, compost and rock phosphate. J. Plant Nutr., 37, 1002–1011.

Çalışkan, S., Yetişir, H., Karanlık, S. (2014). Combined use of green manure and farmyard manure allows better nutrition of organic lettuce. Not. Bot. Hort. Agr., 42(1), 248–254.

Danny, L.R. (1992). Commercial mushroom production. Horticultural Research Institute of Ontario Vineland Station. Publ. – Ont. Minist. Agric. Food, 350(5), 37–38.

Demir, H., Gölükçü, M., Topuz, A., Özdemir, F., Polat, E., Şahin, H. (2003). The effect of different organic fertilizers on the mineral contents of yedikule and iceberg lettuce types grown in organic farming. Akdeniz Univ., J. Fac. Agric., 16(1), 79–85.

DIN 11542:1978-01. Torf für Gartenbau und Landwirtschaft, 52.

Epstein, E. (1997). The Science of Composting. Technomic Publishing Company, Switzerland, 483.

Erdin, E. (2016). Composting of Solid Wastes. http://web.deu.edu.tr/erdin/tr/ders/kati_atik/ders_not/katiatiklarinkompostlastirilmasi.pdf

Fuente, B., Bolan N., Naidu R., Mora, M. (2006). Phosphorus in organic waste-soil systems. Rev. Cienc. Suelo Nutr. Vegetal 6(2), 64–83.

Haug, R.T. (1993). The practical handbook of compost engineering. Lewis Publishers, Boca Raton, FL, 717.

Haynes, R.J., Naidu, R. (1998). Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: a review. Nutr. Cycl. Agro Ecosyst., 51, 123–137.

Hernández, A., Castillo, H., Ojeda, D., Arras, A., López, J., Sánchez, E. (2010). Effect of vermicompost and compost on lettuce production. Chilean J. Agric. Res., 70(4), 583–589.

http://www.byegm.gov.tr/turkce/haber/topraksiz-tarim-jeotermale-gz-koydu/29560

http://www.tarim.gov.tr/Konular/Bitkisel-Uretim/Tarla-Ve-Bahce-Bitkileri/Ortu-Alti-Yetistiricilik

http://www.tuik.gov.tr/PreTablo.do?alt_id=1001

Ismail A., Fun, C.S. (2003). Determination of vitamin C, β-carotene and riboflavin contents in five green vegetables organically and conventionally grown. Malays. J. Nutr., 9, 31–39.

Kacar, B. (1972). Chemical analyses of plant and soil. Ankara Univ., Agric. Fac., 453, Ankara, Turkey, 646.

Kacar, B., Kovancı, İ. (1982). The Analysis of Phosphorus in Plant, Soil and Fertilizers. Ege Univ. Fac. Agric., 354.

Kacar, B., İnal, A. (2008). Plant Analysis. Nobel Press, 1241.

Kaplan, M., Sönmez, S., Alagöz, Z. (2001). Agricultural activity induced environmental pollution in the Antalya region and solution, Int. Symposium Municipal and Industrial Wastes and Their Treatment in 2000's, Istanbul, Turkey, 370–375.

Kaplan, M., Sönmez, S., Polat, E., Demir, H. (2008). Effects of organic and mineral fertilizers on yield and nutritional status of lettuce. Asian J. Chem., 20, 1915–1926.

Kowalchuk, G.A., Naoumenko, Z.S., Derikx, P.J.L., Felske, A., Stephen, J.R., Arkhipchenko, I.A. (1999). Molecular analysis of ammonia-oxidizing bacteria of the subdivision of the class proteobacteria in compost and composted materials. Appl. Env. Microbiology 65, 396–403.

Külcü, R., Yaldız, O. (2004). Determination of aeration rate and kinetics of composting some agricultural wastes. Bioresour. Technol., 93, 49–57.

Kürklü, A., Bilgin, S., Külcü, R., Yaldız, O. (2004). A Study on determination of amount and energy contents of some vegetable biomass wastes. Bioenergy Symp., 69–75.

Kütük, C., Topçuoğlu, B., Demir, K. (1999). Toprağa uygulanan farkli organik materyallerin ıspanak bitkisinde verim ile bazi kalite öğeleri ve mineral madde içerikleri üzerine etkileri. Akdeniz Univ., J. Fac. Agric., 12, 31–36, (in Turkish).

Madeira, A.C., Ferreira, A., De Varennes, A., Vieira, M.I. (2003). SPAD Meter versus tristimulus colorimeter to estimate chlorophyll content and leaf color in sweet pepper. Com. Soil Sci. Plant Anal., 34, 17(18), 2461–2470.

Manal, M.H., El–Mola, G., Saleh., S.M., Shafik, D.A., Esmail, A.A.M. (2012). Effect of adding compost at different depths on the growth of some vegetable crops under net plastic houses. Middle East J. Agric. Res., 1(1), 13–18.

Pearson, D. (1970). Analysis. Determination of L. Ascorbic Acid. International Federation of Fruit-Juice Producers, 17.

Pimentel, M.S., Lana, A.M.Q., De-Polli, H. (2008). Commercial quality of lettuce and carrot consortium and fertilized with organic compound. Embrapa Agrobiol., Bol. Pesqui Desenvolv., 28.

Polat, E., Onus, A.N., Demir, H. 2004. The effects of spent mushroom compost on yield and quality in lettuce growing. Akdeniz Univ., J. Fac. Agric., 17(2), 149–154.

Porto, M.L., Alves, C.J. Souza, P.A., Araujo, C.R., Arruda, A.J. (2008). Nitrate production and accumulation in lettuce as affected by mineral nitrogen supply and organic fertilization. Hortic. Bras., 26(2), 227–230.

Rantala, P.R., Vaajasaari, K., Juvonen, R., Schultz, E., Joutti, A., Mäkelä-Kurtto, R. (1999). Composting of forest industry wastewater sludges for agriculture use. Water Sci. Tech., 40, 187–194.

Rodrigues, E.T., Casali, V.W.D. (1999). Yield and nutrient concentration in lettuce as a function of organic and mineral manuring. Hortic. Bras., 17, 125– 128.

Rodríguez, D.N., Cano, R.P., Figueroa, V.U., Palomo, G.A., Esteban, F.C., Álvarez, R.V. (2008). Producción de tomateen in vernadero con humus de lombrizcomo-sustrato. Rev. Fitotec. Mex., 3, 265–272.

Rooster, L. (1999). Use of compost in vegetable growing. Proeftuinnieuws, 9(6), 29–32.

Sakara, N.A., Zhiltsov, Y.A. (2007). Evaluating the adaptive potential of cabbage cultivars and hybrids in the primore territory. Kartofel Ovoschi, 7, 8–9.

Siomas A.S., Papadopoulou, P.P., Gogras, C.C. (2002). Quality of romaine and leaf lettuce at harvest and during storage. proc. 2nd Balkan Symposium on Vegetables and Potatoes. Acta Hort., 579, 641–646.

Smith, S.R. (2009). A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. Env. Int., 35, 142–156.

Szmidt, R.A.K., Conway, P.A. (1995). Leaching of recomposted spent mushroom substrates (SMS). Sci. Cult. Edible Fungi, 2, 901–905.

Tüzel, Y., Boztok, K., Eltez, R.Z. (1992). Atık kompostun kullanım alanları. Türkiye 4. Yemeklik Mantar Kongresi, Yalova, 2, 5 (in Turkish).

Tüzel, Y., Gül, A., Tüzel, I.H., Ongun, A.R. (2003). Organic cucumber production under greenhouse conditions. Acta Hort., 608, 149–157.

Vidigal, S.M., Ribeiro, C.A., Casali, D.W.V., Fontes, F.E.L. (1995). Response of lettuce (*Lactuca sativa* L.) to the residual effect of organic compost. I. Field trial. Revista Ceres, 42(239), 80–88.

Zheljazkov, V.D., Warman, P.R. (2004). Source-separated municipal solid waste compost application to swiss chrd and basil. J. Env. Quality, 33, 542–552.