 Article

Evaluation of physio-chemical properties and stability of some commercial horticultural substrates by the European Standard Methods

Hyuck-Soo Kim, and Kye-Hoon Kim*

Department of Environmental Horticulture, The University of Seoul, Seoul 130-743, Korea

This study was carried out to analyze physico-chemical properties and to determine stability of the 19 commercially available horticultural substrates in Korea by European standard methods (EN methods). The average pH, EC, T-N, P_2O_5 were 5.44, 0.62dS·m^{-1}, 0.98% and 10.54mg·L^{-1}, respectively. Dry bulk density and particle density were in the range of 124.47~243.16kg/m^3 and 2073.94~2249.99kg/m^3, respectively. Seventeen out of 19 horticultural substrates used in this study were 'very stable'. The other 2 substrates were classified as 'stable'. Korea's own criteria of stability for the organic materials such as growing substrates and compost need to be developed so that farmers can use the optimum organic materials without anxiety.

Key words: Horticultural substrates, European standard methods, Stability

Introduction

Korean market for horticultural substrates has developed through rapid growth of plug seedling production industry, which is estimated to 50 billion wons each year (Kim, 2006). The horticultural substrates go on sale in Korea are composed of organic materials such as coir dust and peatmoss and inorganic materials including perlite, vermiculite and zeolite. The organic materials which are main component of the horticultural substrates are mostly imported.

In the early days of substrate industry there were frequent troubles on the quality of the substrates due to lack of systematic regulation by the government and that of scientific research. Rural Development Administration (RDA) initiated research towards standardization of substrate quality in early 2000's (Kim, 2002) resulting in establishment of the Standard Methods of Substrate Analysis by RDA (RDA method) in 2002 (RDA, 2002). The Korea Artificial Substrates Manufacturers Association (KASMA) made a public announcement for quality standard of substrates in 2009 (KASMA, 2009) with the aim of applying the announcement to the manufacturers and research institutes.

European Committee for Standardization set standard methods for substrates in Europe so that the physico-chemical properties of the substrates in Europe can be managed systematically. The committee also has been carried out continuous research towards international standardization. Kim and Kang (2001) introduced the European Standard Methods for Substrates (EN method) to Korea. Lee et al. (2006a, 2006b) reported the optimum conditions of substrates for seedling production of Chinese cabbage by EN methods. They also carried out research to compare chemical properties of the substrates by EN methods with those by RDA methods (Lee et al., 2006c).

Despite these researches, troubles in using substrates occur every year up to now. Park (2006) reported a case by using poor organic material. Substrates from poor organic materials often cause such troubles as ammonia gas emission, production of organic acids and nitrogen deficiency from denitrification (Lee, 2006).

Stability of substrates measured by oxygen uptake rate (OUR) has been one of the research topics for quality management of growing substrates and soil improvers in Europe. Europeans manage quality of organic material using OUR. Researches on growing substrates and soil improvers using manure and peat performed by Veeken et al. (2003) resulted in development of four-step criteria for stability as shown in Table 1. This method is being used in the Netherlands and the Ireland. European Committee for Standardization (CEN) is reviewing and revising this

Received : December 27. 2009 Accepted : January 18. 2010
*Corresponding author : Phone: +82222102605
E-mail: johnkim@uos.ac.kr

method to enact this method as a European standard method (Verhagen, 2009).

Table 1. Oxygen uptake rate (OUR) criterion of compost (Veeken et al., 2003).

Definition	OUR (mmol O_2/kg VS/h)
Very unstable	> 30
Unstable	15 - 30
Stable	5 - 15
Very stable	< 5

Researches for evaluation of composting degree and stability of compost are being carried out actively in Korea. Rural Development Administration (RDA) strengthened evaluation of stability of compost by complete revision of the fertilizer regulation in October, 2009. However, research for stability of the organic materials, which occupies majority of the horticultural substrates, has not carried out yet. Therefore this study was carried out to analyze physico-chemical properties of the 19 commercially available horticultural substrates in Korea by EN methods and to determine stability of the substrates by OUR.

Materials and Methods

Nineteen horticultural substrates were collected from 12 substrate manufacturers for this study. The collected substrates were analyzed for physical properties such as laboratory compacted bulk density (L_D), dry bulk density (D_B), particle density (D_P), total pore space (P_S), water volume (W_V), air volume (A_V), dry matter content (DM_C), moisture content (M_C) and chemical properties including pH, EC, T-N, P, K, Mg, Ca, Na, organic matter content (C_{om}), ash content (C_{ash}) by EN methods (CEN, 1999a; CEN, 1999b; CEN, 1999c; CEN, 1999d; CEN, 1999e; CEN, 1999f).

Stability of the substrates was determined by OxiTop soil respiration measurement system (OxiTop Control B6M, WTW, Germany) according to DIN 19737. This method is being developed as part of standardization of the analytical methods for growing substrates in European by CEN/TC 223. Appropriate amount of substrate samples, which was equivalent to 3g of the pre-determined organic matter content, was place in OxiTop vessels. One hundred and eight milliliters (mL) of distilled water and 10mL of nutrient solution were added to each vessel. Nutrient solution was composed of 1mL of micro nutrient solution (5.0 g/L EDDHA 6% iron chelate, 1.4 g/L $MnSO_4$, 1.1 g/L $ZnSO_4$, 4.2 g/L $Na_2B_4O_7$, 0.2 g/L $CuSO_4$, 0.13 g/L Na_2MoO_4, 1 ml/L 36% HCl) and 1 L of macro nutrient solution (4.3 g/L NH_4Cl, 5.4 g/L $CaCl_2{\cdot}2H_2O$, 4.3 g/L $MgSO_4{\cdot}7H_2O$, 0.03 g/L $FeCl_3{\cdot}6H_2O$). Ten milliliters of pH buffer (pH 7) and 2.5 mL ATU (N-Allylthiourea) were added using a dispenser. The sample was placed on the shaking table and was let it stand for 4 to 8 hours in the conditioned room. Then the pH of the suspension was controlled to 6.5~7.5.

The CO_2-absorber unit was filled with absorbent-pellets (NaOH-pellets). The vessels were incubated on the shaking table (30℃, 120 rpm) and the pressure was measured during 7 days (2 times/hour).

Oxygen consumption (O_C, mmol O_2/kg OM) was calculated by the equation (1) based on pressure change after a week.

$$O_c = \frac{\triangle P \times 10}{R \times (273.15 + T)} \times \frac{V_{gas} \times 10000}{W \times DM \times OM} \qquad (1)$$

Where, △P is pressure drop in the headspace (kPa); R is the gas constant (83.14 L·kPa·K^{-1}·mol^{-1}); T is measured temperature (℃); W is weight of substrate (kg); DM is dry weight content of the substrate (%); OM is organic matter content of the substrate (%); and V_{gas} is the volume of the gas phase (ml). V_{gas} was calculated by the equation (2).

$$V_{gas} = V_{vessel} - \frac{W \times DM \times 10000}{\rho} - V_{liquid} \qquad (2)$$

V_{vessel}: total volume of vessel (ml)

V_{liquid}: all added liquids (distilled water, nutrient solution, pH buffer, ATU solution)

ρ: calculated sample density (kg · m^{-3})

Sample density (ρ) was calculated by the equation (3).

$$\rho = \frac{1}{\frac{OM \times W \times DM}{1550} + \frac{(1 - OM) \times W \times DM}{2650}} \qquad (3)$$

Oxygen uptake rate (OUR, mmol O_2 · kg^{-1} OM · $hour^{-1}$) was calculated by dividing the amount of oxygen consumption calculated from the above by the elapsed time.

Results and Discussion

Physio-chemical properties of horticultural substrates Dry matter content, moisture content, organic matter content, ash content and laboratory compacted bulk density of the 19 substrates used for this study is shown in Table 2. Moisture content was in the range of 30.00~60.67% with the average of 48.28%. The criteria for average organic matter content for the horticultural substrates suggested at the International substrate manual (Aendekerk et al., 2000) was over 40%, whereas the average organic matter content from this study was 31.21%.

The chemical properties of the substrates used in this study is shown in Table 3. The average pH, EC, T-N, P_2O_5 were 5.44, 0.62dS · m^{-1}, 0.98% and 10.54mg · L^{-1}, respectively. The exchangeable-K, -Mg, -Ca, -Na contents were 126.33, 43.71, 68.36, 171.63mg · L^{-1}, respectively.

Allaire et al. (1996) reported that the optimum pH range for substrates was 5.0~6.5. All the substrates except one used for this study satisfied the pH range by Allaire et al. However, only 8 out of 19 could meet the optimum pH range for horticultural substrates by KASMA, 5.5~7.0. Since EN methods were used for analyzing substrate samples in this study and RDA methods were used for KASMA we analyzed pH of all the substrate samples by RDA method. The pH of 19 substrates by RDA method was in the range of 4.36~5.92 with an average of 5.23, which was even lower than that by the EN method. Lee et al. (2006c) also reported that the average pH of their samples by EN method was 5.29, whereas that by RDA method was 5.15. These result from the difference between EN method and RDA method for pH measurement. Both methods use 1:5 (=substrate:distilled water, v:v) ratio. EN method uses pre-determined laboratory compacted bulk density for this ratio, whereas RDA method does not. Therefore, the pH of the growing substrates needs some pH adjustment to meet the criteria by KASMA.

Table 2. Moisture, dry matter content, organic matter, ash content and laboratory compacted bulk density of substrates by EN method.

Substrate	Dry matter content	Moisture content	Organic matter content	Ash content	L_D*
	---------- % ----------				g L^{-1}
CS**-1	60.33	39.67	27.08	72.91	282.28
CS-2	54.67	45.33	26.73	73.26	303.37
CS-3	64.33	35.67	25.05	74.95	322.17
CS-4	54.00	46.00	35.58	64.42	227.38
CS-5	49.67	50.33	34.42	65.58	276.98
CS-6	54.33	45.67	32.79	67.21	286.28
CS-7	48.67	51.33	26.99	73.00	391.20
CS-8	53.67	46.33	26.53	73.47	290.05
CS-9	44.33	55.67	29.18	70.82	336.56
CS-10	46.00	54.00	35.51	64.49	324.21
CS-11	39.33	60.67	34.97	65.03	274.47
CS-12	42.00	58.00	37.55	62.45	240.48
CS-13	53.00	47.00	33.13	66.87	228.29
CS-14	39.67	60.33	39.14	60.86	258.63
CS-15	47.67	52.33	33.88	66.12	302.01
CS-16	57.33	42.67	26.18	73.82	297.48
CS-17	69.00	31.00	30.00	70.00	243.53
CS-18	53.00	47.00	32.38	67.62	290.01
CS-19	51.67	48.33	25.97	74.03	294.60
Average	51.72	48.28	31.21	68.79	287.89

*Laboratory compacted bulk density, **commercial substrate.

Table 3. Chemical properties of substrates analyzed by EN method.

	pH	EC	K^+	Mg^{+2}	Ca^{+2}	Na^+	P_2O_5	T-N
	1:5	dS m^{-1}	------------------------------	------	mg L^{-1}	------	---------------------------------	%
CS*-1	5.37	0.74	66.10	85.73	227.28	157.14	11.21	1.08
CS-2	5.62	0.78	64.55	91.17	283.32	190.43	10.75	0.75
CS-3	5.53	0.55	49.72	53.23	179.60	144.00	9.24	0.31
CS-4	5.21	0.42	76.75	30.08	34.93	145.20	9.90	0.72
CS-5	5.19	0.66	96.92	76.06	102.66	233.84	7.85	1.09
CS-6	5.39	0.65	96.63	63.62	62.02	210.09	10.55	0.84
CS-7	6.10	0.71	82.61	15.25	8.94	295.83	2.90	0.19
CS-8	5.50	0.71	172.94	69.64	78.28	80.68	18.95	1.25
CS-9	5.40	0.60	143.32	55.33	61.48	98.89	11.79	1.09
CS-10	4.75	0.85	306.74	50.13	33.85	188.14	10.64	1.07
CS-11	5.97	0.47	143.69	12.59	10.68	150.99	13.06	0.98
CS-12	5.13	0.57	113.21	35.23	40.34	172.58	11.21	1.29
CS-13	5.25	0.50	70.31	32.96	36.01	175.96	7.27	1.19
CS-14	5.70	0.66	222.75	9.97	6.90	172.70	16.56	1.28
CS-15	5.85	0.57	172.82	15.20	18.53	170.41	14.76	1.21
CS-16	5.51	0.41	61.57	26.41	39.75	135.31	4.77	1.05
CS-17	5.22	0.54	165.83	15.07	22.31	134.83	0.73	1.13
CS-18	5.39	0.82	222.61	42.07	11.09	248.19	11.16	1.09
CS-19	5.27	0.50	71.29	50.77	40.89	155.69	17.03	1.09
Average	5.44	0.62	126.33	43.71	68.36	171.63	10.54	0.98

*Commercial substrate.

Each substrate showed wide variation in the inorganic ion contents. KASMA established self-guaranteed criteria for quality management of horticultural substrates except for pH, NO_3-N and pollutants. And there is not any criteria for inorganic ions of horticultural substrates. Therefore care must be taken for contents of inorganic ions in the horticultural substrates since there is a possibility for phytotoxicity resulted from salt accumulation due to high inorganic ion contents.

Table 4 shows physical properties of the substrates used in this study. Dry bulk density and particle density were in the range of 124.47~243.16 kg/m_3 and 2073.94~2249.99 kg/m_3, respectively. Considering the optimum range of total pore space (>85%), water volume (65~70%) and air volume (20~30%) for plant growth from previous researchers (De boodt and Verdonck, 1972; Bunt, 1974; Fonteno and Nelson, 1990), all the horticultural substrates used in this study met total pore space cirteria, whereas only 6 out of 19 samples were in the optimum range. Although manufacturers of horticultural substrates can satisfy optimum range of water and air volumes when they make their products, KASMA may need its own criteria established by researches on country-specific cultivation methods as well as type of crops.

Stability of horticultural substrates Pressure change in OxiTop vessel during the period of 1 week for 19 horticultural substrates is shown in Figure 1. Although change of pressure change in OxiTop vessels was different depending upon horticultural substrate, the pressure change of all the substrates increased during the first 8 hours from initiation. This was due to generated water vapor from evaporation of the added distilled water. Returning of the vapor pressure to the initial point at the last stage seemed to be resulted from consumption of all the oxygen in the vessels.

The lowest pressure in the OxiTop vessels during the experiment was in the range of -4~-45 hPa. Time to reach to the lowest pressure ranged from 2044 to 8512 minutes depending upon horticultural substrate. The volume of the gas phase and density of the horticultural substrates used in this study were in the range of 755.44~787.46 mL (ave.

Table 4. Physical properties of substrates analyzed by EN method.

Substrate	D_{BD}[z]	D_P[y]	P_S[x]	W_V[w]	A_V[v]
	------------ kg m^{-3} ------------		---------------------------- % -----------------------------		
CS[u]-1	191.51	2222.72	91.38	67.89	23.49
CS-2	211.22	2227.39	90.52	74.03	16.49
CS-3	243.16	2249.99	89.19	72.99	16.20
CS-4	148.44	2115.73	92.98	63.82	29.16
CS-5	174.50	2129.76	91.81	73.85	17.95
CS-6	188.06	2149.78	91.25	72.24	19.01
CS-7	202.01	2223.96	90.92	58.50	32.41
CS-8	161.56	2230.11	92.76	57.13	35.62
CS-9	177.49	2195.33	91.91	68.08	23.83
CS-10	200.22	2116.60	90.54	78.35	12.19
CS-11	127.87	2123.11	93.98	64.14	29.83
CS-12	124.47	2092.39	94.05	69.46	24.95
CS-13	145.65	2145.56	93.21	69.22	23.99
CS-14	129.46	2073.94	93.76	78.31	15.44
CS-15	162.66	2136.37	92.39	70.79	21.59
CS-16	207.35	2234.85	90.72	69.04	21.68
CS-17	180.87	2184.84	91.72	63.02	28.70
CS-18	179.83	2154.87	91.65	65.17	26.49
CS-19	196.62	2237.58	91.21	70.37	20.84
Average	176.47	2170.78	91.89	68.76	23.13

[z]Dry bulk density, [y]particle density, [x]total pore space, [w]water volume, [v]air volume, [u]commercial substrate.

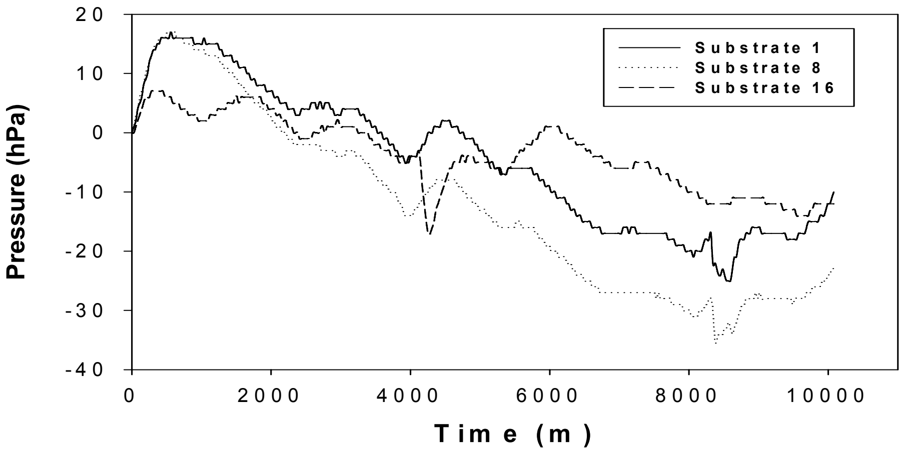

Fig. 1. Pressure drop of substrates (number 1, 8, 16) over time for aerobic degradation in Oxitop.

774.43 mL) and 172.30~304.19 kg · m^{-3} (ave. 235.24 kg · m^{-3}), respectively.

Figure 2 shows the oxygen uptake rate (OUR) calculated from change of pressure. Interpretation of these results according to OUR criterion of compost (Veeken et al., 2003) and stability stage of the organic materials such as compost and peat revealed that 17 out of 19 horticultural substrates used in this study were 'very stable' (<5 mmol O_2/kg VS/h). These were equivalent to stability level of the organic matter in soil or that of the 5 month old compost. The other 2 substrates were classified as 'stable' (5~15 mmol O_2/kg VS/h) which is equivalent to the stability of 3-4 week old fresh compost. Carlile and Dickimson (2004) reported that substrates made of peat

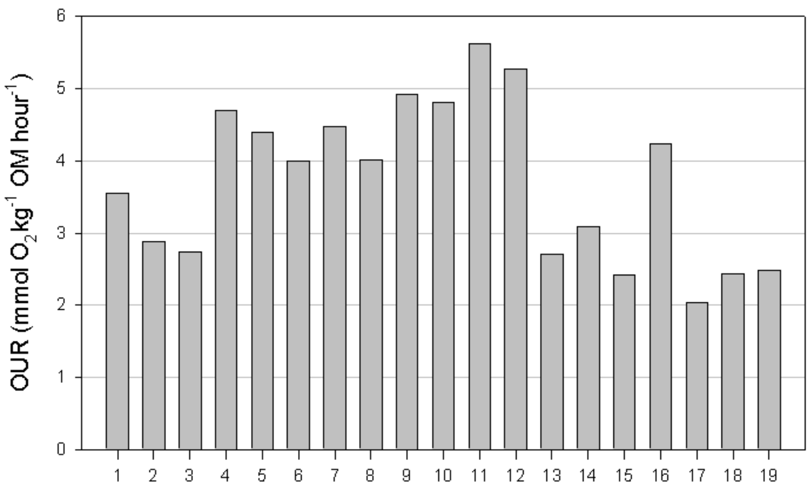

Fig. 2. The oxygen uptake rate (OUR) of the substrates used in this study.

were more stable than that of bark and paper mill waste, which supported the results of this study.

Since not all the horticultural substrates used in this study were very stable and not all the management of coir dust and peat moss manufacturers are not uniform, research on stability of growing substrates needs to be carried out continuously. Moreover Korea's own criteria of stability for the organic materials such as growing substrates and compost need to be developed so that farmers can use the optimum organic materials without anxiety.

References

Aendekerk, Th.G.L., H. Cevat, N. Dolmans, C. van Elderen, J.A. Kipp, C. de Kreij, C. Sonneveld, J.B.G.M. Verhagen, and G. Wever. 2000. International substrate manual. Elsevier. Netherlands.

Allaire, S.E., J. Caron, I. Duchesne, L.E. Parent, and J.A. Rioux. 1996. Air filled porosity, gas relative diffusivity and tortuosity: Indices of Prunus xcistena sp. growth in peat substrate. J. Amer. Soc. Hort. Sci. 121:236-242.

Bunt, A.C. 1974. Some physical and chemical characteristics of loamless pot-plant substrates and their relation to plant growth. Acta Hort. 37:1954-1965.

Carlile, W.R., and K. Dickinson. 2004. Dehydrogenase as an indicator of microbial activity in growing media. Acta Hort. 644:517-523.

De Boodt, M., and O. Verdonck. 1972. The physical properties of the substrates in horticulture. Acta Hort. 26:37-44.

European Committee for Standardization (CEN). 1999a. Soil improvers and growing media-Determination of pH. CEN. prEN 13037.

European Committee for Standardization (CEN). 1999b. Soil improvers and growing media-Determination of electrical conductivity. CEN. prEN 13038.

European Committee for Standardization (CEN). 1999c. Soil improvers and growing media-Determination of organic matter and ash. CEN. prEN 13039.

European Committee for Standardization (CEN). 1999d. Soil improvers and growing media-Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density. CEN. prEN 13040.

European Committee for Standardization (CEN). 1999e. Soil improvers and growing media-Determination of physical properties-Dry bulk density, air volume, water volume, shrinkage value and total pore space. CEN. prEN 13041.

European Committee for Standardization (CEN). 1999f. Soil improvers and growing media-Extraction of water soluble nutrients. CEN. prEN 13652.

Fonteno, W.C., and P.V. Nelson. 1990. Physical properties and plant response to rockwool-amended media. J. Amer. Soc. Hort. Sci. 115(3):375-381.

Kim, K.H., and J.Y. Kang. 2001. Introduction to European Standard methods for physical and chemical analysis of horticultural substrates. Kor. J. Hort. Sci. Technol. 19(2): 179-185.

Kim, Y.B. 2002. Quality Calibration Method of Substrate. Proceedings of the Korean Society for Bio-Environment Control Conference. 203-211.

Kim, Y.B. 2006. Distribution status and Development Challenges of the Horticultural Substrate Industry. Korean Study Group of Artificial Substrates. 1:142-150.

Korea Artificial Substrates Manufactures Association. 2009. Quality Standard of Artificial Substrates.

Lee, H.H., S.K. Ha, B.H. Kim, Y.J. Seol, and K.H. Kim. 2006a. Optimum physical condition of peatmoss-based substrate for growth of Chinese cabbage (*Brassica campestris* L. ssp.) plug seedling. Kor. J. Hort. Sci. Technol. 24(3): 322-329.

Lee, H.H., S.K. Ha, K.H. Kim, J.H. Ryu, and E.H. Park. 2006b. Optimum physical condition of coir-based container substrate for growth of Chinese cabbage (*Brassica campestris* L. ssp.)

plug seedling. Kor. J. Hort. Sci. Technol. 24(3): 330-337.
Lee, H.H., K.H. Kim, and J.Y. Kang. 2006c. Comparison of the European Standard method and the Rural Development Administration method for determining chemical properties of horticultural substrates. Kor. J. Hort. Sci. Technol. 24(3): 425-430.
Lee, J.W. 2006. Use-cases of Domestic Horticultural Substrate Products and Improvement Programs. Korean Study Group of Artificial Substrates.1:211-224.
Park, S.D. 2006. Occurrence of substrate accidents and reference of manufacturing process. Korean Study Group of Artificial Substrates. 1:203-210.
Rural Development Administration. 2002. Standard analysis methods of horticultural substrate. NIAST, Suwon.
Veeken, A.H.M., V. de Wilde, and H.V.M. Hamelers. 2003. Oxitop measuring system for standardised determination of the respiration rate and N-mineralisation of organic matter in waste material, compost and soil. Wageningen University & NMI.
Verhagen, J.B.G.M. 2009. Stability of growing media from a physical, chemical and biological perspective. Acta Hort. 819:135-142.

유럽표준분석법에 의한 원예용 상토의 이화학성 및 안정성 평가

김혁수 · 김계훈*

서울시립대학교 환경원예학과

본 연구는 현재 유통 중에 있는 원예용 상토에 대해 이화학적 특성 및 안정도를 조사하여 상토이용의 최적화를 도모하기 위하여 수행하였다. 이를 위하여 12개 업체에서 생산하는 19 종류 원예용 상토를 수집하여 유럽표준분석법에 준해 상토의 이화학성을 분석하였다. 또한 이 결과를 이용하여 유럽에서 사용 중인 산소호흡률 측정방법에 따라 상토의 안정도를 평가하였다. 원예용 상토의 이화학성은 건물함량 39.33~69.00%, 수분함량 31.00~60.67%, 유기물함량 25.05~39.14%, 회분함량 60.86~74.95%, 실험실가밀도 227.38~391.20g · L^{-1} pH 4.75~6.10 EC 0.41~0.85 dS · m^{-1} T-N 0.19~1.29%, P_2O_5 0.73~18.95 mg · L^{-1}로 각각 조사되었다. 양이온 K, Mg, Ca, Na은 각각 49.72~306.74 mg · L^{-1}, 9.97~91.17 mg · L^{-1}, 6.90~283.32 mg · L^{-1}, 80.68~295.83 mg · L^{-1}의 범위를 나타내었다. 또한 가밀도 124.48~243.16 kg · m^{-3}, 진밀도 2073.94~2249.99 kg · m^{-3}, 총공극률 89.19~94.05%, 액상 57.14~78.35%, 기상 12.19~35.62%로 조사되었다. 원예용 상토의 산소호흡률은 2.03~5.63 mmol O_2 · kg OM $hour^{-1}$로 선행연구를 통해 설정된 유기물질의 안정도 평가기준과 비교시 19점의 원예용 상토 중 17점의 상토에서 '매우 안정'의 단계로 조사되었으며, 나머지 2점의 상토에 대해서도 '안정' 단계로 평가되었다. 향후 상토의 산소호흡률을 이용한 안정도 평가를 통해 최적조건의 상토가 지속적으로 관리될 수 있을 것으로 판단된다.