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Investigation of topsoil production from marine dredged materials (DMs) in Turkey for urban landscaping works

Baris Güzel [a,*], H. Merve Başar [b], Kemal Güneş [a], Serpil Yenisoy-Karakaş [c], Leyla Tolun [a]

[a] Environment and Cleaner Production Institute, TUBITAK Marmara Research Center, Gebze, 41470, Kocaeli, Turkey
[b] Department of Chemical Engineering, Faculty of Engineering and Architecture, Beykent University, Sarıyer, 34398, Istanbul, Turkey
[c] Department of Chemistry, Faculty of Science and Art, Abant Izzet Baysal University, Gölköy, 14030, Bolu, Turkey

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ABSTRACT

As known, marine dredged materials (DMs) are highly nuisance wastes if they are not correctly reused or removed. In this work, the usability of DMs to the technical terms as manufactured topsoil (MT) in the urban landscaping works is discussed. Firstly, the leaching potentials of DMs were determined according to the related legislations to identify their hazardousness features. Secondly, DMs were subject to some treatment stages such as sieving, desalination, organic amelioration via peat and sheep manure, and pH adjustment to turn into an alternative natural soil pursuant to the British Standard in the scope of soil quality improvement studies as there is not any national standard in Turkey for the production of topsoil from different materials. Then, MT mixtures were prepared with washed and unwashed DM, peat and sheep manure in different mixing ratios (v/v); 33%, 50% and 67% DM, respectively. Consequently, high quality grass seed mixtures used for the landscaping applications were monitored for six months. The results demonstrate the availability of DM as alternative MT in the urban landscaping areas. Thus, important data were obtained as to the use of DM at alternative areas such as green city, green roof, shopping centers, organized industry, etc.

1. Introduction

Topsoil is the top layer of the soil structure and rich in terms of organic content. It provides the plant production and development in order to include the microbial activities. Thus, manufactured topsoil (MT) is significant in the municipality landscaping applications even though it possesses unstable specifications such as soil physical structure, nutrient concentrations and so on [1]. Topsoil mixtures to be used for the landscaping works have been formed from sandy materials. They are generally mixed with different kinds of organic based-materials (yard waste, peat or animal manure) so as to enhance their organic contents. However, these additives have different effects on the quality of topsoil mixtures with regard to the physical structures and chemical contents [2].

Dredged Material (DM) is the excavated material from the bottom of marine/fresh water at the end of the dredging operation and the excavation of this material provides the expansion of current channel, harbor and marina areas, deepening of the navigation channel, restoration of contaminated bay, gulf and estuary, and improvement of water quality, respectively [3, 4, 5, 6]. Marine DMs can be used as a sandy raw material in the production of MT for the landscaping instead of highly demanded natural soil. Even though MT is significant in the municipality's landscaping applications, they require some pre-treatment processes such as dewatering, desalination, pH adjustment and organic amelioration due to variable physico-chemical characteristics and especially having a saline content [1, 7, 8]. Their organic contents and physical conditions must be harmonized with organic waste-based additives (yard waste, wastepaper, wood chips), biosolids (sewage sludge or animal manure) or peat, which occurs with the deposition of decomposed plant materials, in order to improve the soil structure and increase the organic content of MT. However, the quality of topsoils from the viewpoint of the soil structure, erosion resistance, biological processes and nutrient availability have been affected differently by organic based materials [9, 10, 11]. The degradation of complex organic materials in soil occurs with the composting process ensures and it provides the enrichment of soil [9].

The investigation of the beneficial use of marine DMs as MT in urban landscaping applications technically requires the topsoil production specifications on the national basis. Unfortunately, there is no any standard about the topsoil specifications in Turkey. The latest version of British Standard (BS 3882:2015) [12] can be assessed for that purpose.

* Corresponding author.
E-mail address: baris.guzel@tubitak.gov.tr (B. Güzel).

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DM possesses generally a high pH value, saline content and low organic matter. These are the most crucial parameters for the production of MT due to the nature of marine originated DMs. It is clear that the monitoring of desalination and dewatering processes should be initially carried out in order to determine the time to reach the intended salinity and handling features. Then, organic content testing should be followed out so as to examine the quantities of organic amelioration. Finally, pH adjustment is made to enhance nutrients' availability for the plant growth [13].

A variety of studies has been carried out for the production of MT from marine DMs up till now. Some of them can be declared as follows: Joo et al. (2008) paid particular attention to the salt-tolerant turf grass variety among warm and cool-season grasses on the reclaimed sea sand dredged from the Yellow Sea so as to benefit at the new Incheon International Airport landscaping areas in the Republic of Korea [14]. Sheehan and co-workers (2010) investigated the availability of MT production by mixing Port Waterford's harbour (one of Ireland's largest commercial port and 500,000 tons/year of DM are removed) DM together with organic household wastes [13]. In a study made in South Korea, Kim and Pradhan (2015) have also turned to account the mechanical and germination features of dredged soil enhanced with a high volume of organic matter (humic acid) and stabilizer (slag cement) for plant growth [15]. Topsoil manufactured from DMs has also been used in projects throughout the United States of America. Some notable projects are the recreational fields at Pearl Harbour, Hawaii and in landscaping works across the city of Toledo, Ohio [16]. One of the crucial investigation on the usability of DM as MT was also carried out in University of Strathclyde in Glasgow/Scotland. The full-scale soil factory having 2,000 tons of topsoil production capacity per week (£ 5.20/ton topsoil selling price) was constructed in Clyde/Glasgow [17, 18].

In addition, there are plenty of practices on the utilization of DM in various beneficial use areas worldwide [7, 13, 14, 15, 16, 19, 20, 21, 22, 23, 24]. However, dumping of DM at sea in Turkey has been the first and most preferred alternative until now. Upland disposal in low quantities has been followed after dumping at sea alternative. Unfortunately, there are very few beneficial use applications of DMs, particularly utilization as MT in landscaping. As it is well known, natural resources are in danger of extinction; thus, there is a need for new soil and soil-like resources like DM for plant growth and development.

To sum up, the goal of this study is to investigate the usability of marine DMs in the technical perspective together with organic additives (peat and sheep manure) in the production of MT for urban landscaping applications and to decide the best topsoil mixing ratio and content. It is thought that it will play a predominant role to reveal other national beneficial use attempts. Furthermore, the usage of DM was well tried together with the sewage sludge, green manure, composts of bio-waste, gypsum, lime and clay minerals as promoter for the amendment of geotechnical soil structure and organic additive for the production of MT in the previous studies [2, 9]. In this study, the improvement of organic content and physical structure of DM were achieved with the addition of peat and sheep manure as additives. This study is a reference for the evaluation of similar DMs.

2. Materials and methods

2.1. Materials

2.1.1. Dredged materials

Sampling studies of DMs were carried out at five different ports located in the shores of Turkey (Mediterranean, Marmara, Aegean and Black Sea). The related sampling points are Rize Port (DM-1), Muğla Göcek Marina (DM-2), Mersin International Port (MIP) (DM-3), Izmir PETKIM Container Port (DM-4) and Kocaeli TUPRAS Yarımca Port (DM-5), respectively, and are given in Fig. 1 together with their pie charts showing the grain size distributions of DMs. Sampling studies were made with different dredging equipment such as bucket ladder dredger, catamaran crane, backhoe and excavator, respectively, prior to beneficial use applications.

2.1.2. Natural soil, peat and sheep manure

Natural soil obtained from Agriculture Department of The Scientific and Technological Research Council of TURKEY Marmara Research Center (TUBITAK MAM) was used in the preparation of control specimens of MT samples. Peat media in 10-liters-packages was taken from Yeniçağa/Bolu and also sheep manure was received from Gebze-Pelitli Village/Kocaeli in order to enhance the organic contents and to develop the physical structures of MTs, respectively.

Fig. 1. Five sampling points in the shores of Turkey and their pie charts showing the particle size distributions (Source: TUBITAK MAM Environment and Cleaner Production Institute Geographic Information System Group).

Table 1
Preparation of the mixtures ($DM_{Mixtures}$) from DMs having the identical particle size distributions.

Name of Mixture	DMs in the Mixtures	Particle Size Distributions
$DM_{Mixture-A}$	DM-1, DM-2, DM-3	Gravel (%): 18.21 ± 0.59 Sand (%): 60.08 ± 0.94 Silt-Clay Mixture (%): 21.71 ± 0.70
$DM_{Mixture-B}$	DM-4, DM-5	Gravel (%): 58.98 ± 0.93 Sand (%): 45.32 ± 0.71 Silt-Clay Mixture (%): 5.70 ± 0.18

2.1.3. *Grass seed*

High quality lawn seed mixture comprised of 20% Lolium perenne (STRAVINSKY), 30% Lolium perenne (TROYA), 35% Festuca rubra (CORAIL) and 15% Poa pratensis (EVORA) was used as landscaping grass in the entire topsoil samples. These and similar high quality grass mixtures are widely used in urban landscaping studies in United Kingdom, USA and many European countries.

2.1.4. *Preparation of topsoil samples*

For the beneficial use of DMs as MTs in the landscaping applications, DMs were sieved from 5 mm sieve at first and then, two different DM mixtures ($DM_{Mixture-A}$ and $DM_{Mixture-B}$) were prepared from five DM samples having the identical particle size distributions as shown in Table 1.

The main reason for the selection and mixing of DMs as two mixture samples in this study is to focus on the evaluation of different pre-treatment scenarios on MT production and grass growth performance of prepared topsoil samples by reducing number of samples. The base point for the selection of samples is to have similar particle size distribution. 3 kg $DM_{Mixture}$ sample was prepared by mixing an equal amount of each DM.

Experimental methodology for the preparation of DMs as MT instead of natural soil in landscaping works is illustrated in Fig. 2. Raw marine DMs have moderate water content, slightly saline and high alkaline nature, low total nitrogen (TN), low organic matter content as well as high C/N ratio, respectively. It is a known fact that these physico-chemical contents are unfavorable for grass growth pursuant to "BS 3882:2015-Topsoil specifications"; consequently, some DM pre-treatment processes are required for MT production. At first, two $DM_{Mixture}$ samples screened from 5 mm sieve (for debris removal) were separated into two parts in order to explore the salinity effect on grass growth. Then, desalination (washing) process was performed for one portion of $DM_{Mixture}$ samples at 170 rpm in HS 501 model KIKA-WERKE shaking machine in order to reduce electrical conductivity (EC) value below 2 mS/cm (saltless) which is the convenient level for plant germination in MTs production. At the end of the washing process, the washed $DM_{Mixture}$ samples were dewatered and filtered through Buchner funnel using filter paper. In this laboratory-scale study, the amount of water (leachate) produced as a result of DM washing-dewatering process was negligible. Therefore, it was discharged to the sewerage system. If the results obtained in this study are taken directly into the application, the disposal of the leachate, which may occur in large volumes, will not create any problems for environment. Because, the leachate analysis results of DMs in Table 2 shows that they do not contain any organic or inorganic pollutants. Thus, the leachate can be discharged to the marine environment in a controlled manner as it will not cause environmental problems. The other part of DMs left as saline for comparison. Afterwards, both washed and unwashed $DM_{Mixture}$ samples were blended with peat and sheep manure in different mixing ratios (33%, 50% and 66% $DM_{Mixture}$) in order to enhance their physical properties and organic contents. Due to the high alkaline nature of DMs, 30 g of $FeSO_4.2H_2O$ (Iron (II) Sulfate Dihydrate) were added into each MT samples in order to adjust pH within the target neutral pH range of 6.50–7.50 for potential nutrient uptake [13]. Control

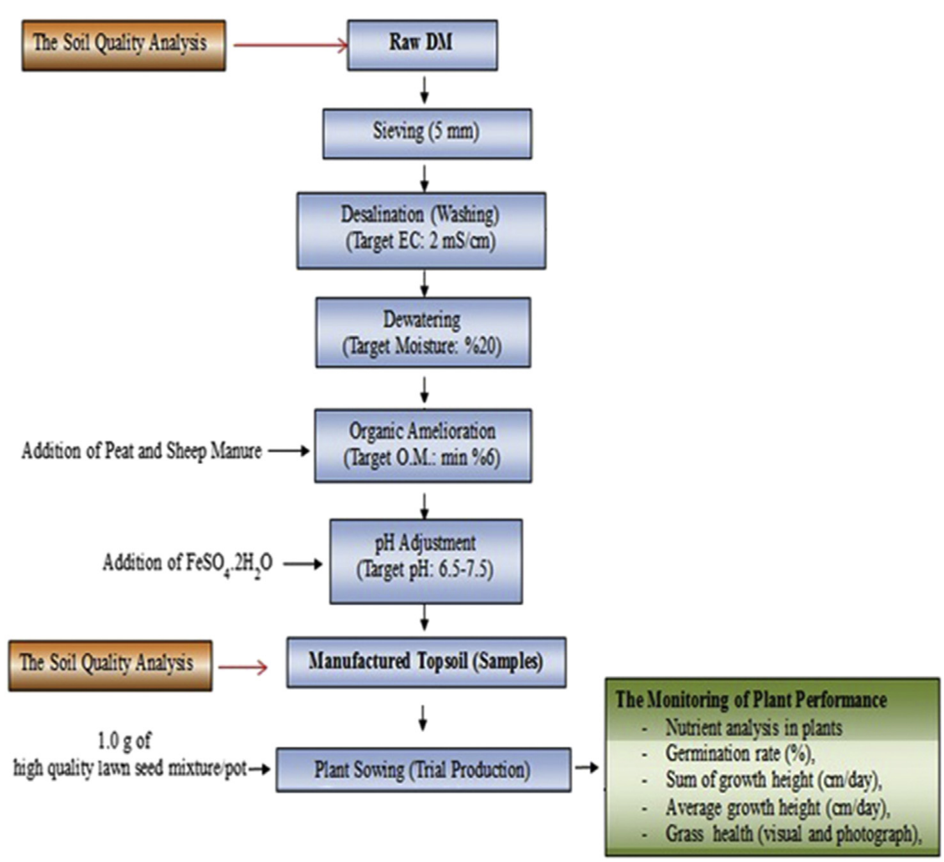

Fig. 2. Experimental methodology for the production of topsoil samples.

Table 2
Leachabilities and heavy metal contents of DMs together with "ADDDY-Appendix 2" and "AYY-Appendix-3B" quality criteria.

Parameters	Methods	DM-1	DM-2	DM-3	DM-4	DM-5	ADDDY-Appendix-2 limits		
							Inert Waste Class III	Non-Hazardous Waste Class II	Hazardous Waste Class I
Leachate (L/S = 10 L/kg)									
As (mg/l)	EPA 6020A:2007	0.0118 ± 0.0021	0.0098 ± 0.0018	0.0044 ± 0.0008	0.0287 ± 0.0052	0.0050 ± 0.0009	0.05	0.2	2.5
Ba (mg/l)		0.0496 ± 0.0042	0.0289 ± 0.0025	0.0595 ± 0.0051	0.0508 ± 0.0043	0.0404 ± 0.0034	2	10	30
Cd (µg/l)		0.00061 ± 0.00005	0.00029 ± 0.00002	0.0001 ± 0.00001	<0.00005	0.00013 ± 0.00002	0.004	0.1	0.5
Cr (mg/l)		0.00854 ± 0.00050	0.00120 ± 0.00007	0.00091 ± 0.00005	0.00013 ± 0.00001	0.00042 ± 0.00002	0.05	1	7
Cu (mg/l)		0.3730 ± 0.0326	0.0181 ± 0.0016	0.0069 ± 0.0006	0.0149 ± 0.0013	0.0064 ± 0.0006	0.2	5	10
Hg (µg/l)	SM-3112			<0.00013			0.001	0.02	0.2
Mo (µg/l)	EPA 6020A:2007	<0.0005	0.1301 ± 0.0065	0.0288 ± 0.0014	0.0374 ± 0.0019	0.0320 ± 0.0016	0.05	1	3
Ni (mg/l)		0.0132 ± 0.0016	0.0367 ± 0.0043	0.0047 ± 0.0006	0.0082 ± 0.0010	0.0017 ± 0.0002	0.04	1	4
Pb (mg/l)		0.0586 ± 0.0060	0.0016 ± 0.0002	0.0015 ± 0.0002	0.0012 ± 0.0001	0.0009 ± 0.0001	0.05	1	5
Sb (mg/l)		0.0014 ± 0.0002	0.0120 ± 0.0017	0.0058 ± 0.0008	0.0029 ± 0.0004	0.0089 ± 0.0012	0.006	0.07	0.5
Se (µg/l)		0.0013 ± 0.0003	0.0011 ± 0.0002	<0.0010	0.0011 ± 0.0002	0.0012 ± 0.0003	0.01	0.05	0.7
Zn (mg/l)		0.2970 ± 0.0170	0.0251 ± 0.0014	0.0138 ± 0.0008	0.0155 ± 0.0009	0.0126 ± 0.0007	0.4	5	20
Cl^- (mg/l)	SM-4110B	436.9 ± 24.0	1,397.9 ± 76.7	768.2 ± 42.2	950.1 ± 52.2	474.4 ± 26.0	80	1,500	2,500
F^- (mg/l)		0.68 ± 0.03	7.06 ± 0.35	0.78 ± 0.04	0.67 ± 0.03	0.99 ± 0.05	1	15	50
SO_4^{2-} (mg/l)		100.9 ± 1.1	221.1 ± 2.4	162.2 ± 1.7	186.4 ± 2.0	93.8 ± 1.0	100 (600)	2,000	5,000
DOC (mg/l)	SM-5310B	1.9 ± 0.1	1.9 ± 0.1	2.9 ± 0.2	2.1 ± 0.1	3.3 ± 0.2	50	80	100
TDS (mg/l)	SM-2540C	1,510 ± 29	2,960 ± 57	1,564 ± 30	2,040 ± 39	1,104 ± 21	400	6,000	10,000
Phenol (mg/l)	SM-5530D			<0.07			0.1	-	-
Solid Matrix									
TOC (mg/kg)	SM-5310B	26,270 ± 1340	1,209 ± 62	3,085 ± 157	2,318 ± 118	2,319 ± 118	30,000	50,000	60,000
BTEX (mg/kg)	EPA 8015C			<0.5			6	-	-
PCBs (mg/kg)	ISO 10382			<0.1			1	-	-
Hydrocarbons (mg/kg)	BS EN 14039	85 ± 1	<65	<65	<65	<65	500	-	-
LOI (%)	TS EN 12879	7.17 ± 0.10	5.63 ± 0.08	4.44 ± 0.06	4.72 ± 0.07	3.42 ± 0.05	-	-	100,000
Heavy Metals	Methods						Hazards	Risk Phrase(s)	AYY-App.-3B limits
Pb (mg/kg)	ISO 11885	40.6 ± 2.4	2.1 ± 0.1	31.9 ± 1.9	13.0 ± 0.8	7.8 ± 0.5	H5, H6, H10, H14	R: 33, 61, 62, 20/22, 26/27/28, 50/53	1,000 (0.1 %)
Cd (mg/kg)		0.77 ± 0.05	<0.10	0.36 ± 0.02	0.43 ± 0.03	0.09 ± 0.01	H6, H7, H10, H11, H14	R: 26, 45, 62, 63, 68,48/23/25, 50/53	1,000 (0.1 %)
Cr (mg/kg)		14 ± 1	2287 ± 81	599 ± 21	140 ± 51	17 ± 1	H11, H14	R: 11, 40, 52	10,000 (1 %)
Cu (mg/kg)		139 ± 9	13 ± 1	38 ± 3	23 ± 2	12 ± 1	H3A, H7, H14	R: 11, 52, 36/37/38	20,000 (2 %)
Ni (mg/kg)		95 ± 5	1834 ± 100	251 ± 14	132 ± 7	9 ± 1	H7, H13, H14	R: 40, 43, 48/23, 52/53	10,000 (1 %)
Zn (mg/kg)		238 ± 11	39 ± 2	105 ± 51	128 ± 6	79 ± 4	H3A, H14	R: 15, 17, 50/53	2,500 (0.25 %)
As (mg/kg)		8.8 ± 0.7	13.7 ± 1.2	8.5 ± 0.7	347.0 ± 29.4	22.1 ± 1.9	H6, H14	R: 23/25, 50/53	2,500 (0.25 %)
Hg (mg/kg)	EPA 7473	0.040 ± 0.006	0.012 ± 0.002	0.025 ± 0.004	2.330 ± 0.336	1.300 ± 0.187	H6, H10, H14	R: 26, 61, 48/23, 50/53	1,000 (0.1 %)

samples were also prepared same mixing ratios by using natural soil instead of $DM_{Mixture}$ sample. Control and MT samples were put into 2 L (10 × 20.0 cm) plastic pots. Sheehan et al. (2010) [13] have also performed similar topsoil production processes with pre-treatment.

2.2. Methods

Whole studies and analysis handled under the scope of this study were performed in the accredited laboratories of TUBITAK MAM Environment and Cleaner Production Institute. The laboratories of interest possess national and international accreditation certificates from Turkish Accreditation Agency (TURKAK) in accordance with TS EN ISO/IEC 17025:2012 standard since July 16, 2010 and German Accreditation Council DAR/DAP (Deutscher Akkreditierung Rat) since December 17, 2002, respectively. Besides, the laboratories received "Measurement and Analysis of Environmental Qualification Certificate" from the Republic of Turkey Ministry of Environment and Urbanization on February 21, 2011.

On the other hand, leaching potentials and heavy metal concentrations of DMs should be determined in compliance with "The Waste Management Regulation (AYY)" [25] and "The Regulation on the Landfilling of Waste (ADDDY)" [26] prior to the selection of appropriate beneficial use application in real case due to the requirements of Turkish Legislation.

2.2.1. Leaching properties of DMs

In accordance with the chemical criteria of the European Waste

Table 3
Soil quality analysis results of topsoil samples' components.

Parameters	$DM_{Mixture-A}$	$DM_{Mixture-B}$	Natural Soil	Peat	Sheep Manure	Methods	References for the Limit values
Solid content (w%)	65.51 ± 0.85	79.69 ± 1.04	94.85 ± 1.24	69.68 ± 0.91	39.66 ± 0.52	TS 9546 EN 12880:2002	-
pH (aq.sol.)	8.55 ± 0.06	9.26 ± 0.07	7.88 ± 0.06	7.35 ± 0.05	7.63 ± 0.06	TS ISO 10390:2013	[39]
EC (mS/cm)	6.25 ± 0.13	2.97 ± 0.07	0.35 ± 0.01	3.66 ± 0.08	1.83 ± 0.04	TS ISO 11265: 1996	[40]
TOC (g/kg)	29.38 ± 1.91	48.58 ± 3.16	7.69 ± 0.50	19.17 ± 1.25	211.51 ± 13.75	TS 8336:1990	-
TN (mg/kg)	510 ± 13	153 ± 4	687 ± 17	10,700 ± 266	24,234 ± 603	TS 8337 ISO 11261:1996	[41]
TP (mg/kg)	386 ± 10	1,029 ± 27	481 ± 13	2,253 ± 59	5,543 ± 145	SM-4500 P	[41]
Organic matter (w %)	5.78 ± 0.04	4.60 ± 0.03	2.61 ± 0.02	37.68 ± 0.24	28.70 ± 0.19	TS 8336:2008	[39]
Soil Texture	Sandy Loam	Sandy Loam	Sandy Loam	Clay	Clay	ASTM D422-63:2007	-
-Sand (%)	72.44 ± 2.33	78.13 ± 2.52	74.05 ± 2.38	24.47 ± 0.38	30.45 ± 0.49	Bouyoucos Hydrometer	
-Silt (%)	14.76 ± 0.23	11.93 ± 0.38	10.98 ± 0.17	11.36 ± 0.18	8.12 ± 0.13		
-Clay (%)	12.80 ± 0.20	9.94 ± 0.32	14.97 ± 0.24	64.17 ± 2.07	61.43 ± 1.98		
Micronutrients;							
Fe (mg/kg)	18.350 ± 0.275	6.082 ± 0.091	1.800 ± 0.027	25.420 ± 0.386	6.589 ± 0.100	TS ISO 14870/T1:2009 (DTPA Method)	[42]
Cu (mg/kg)	3.428 ± 0.294	0.791 ± 0.068	0.246 ± 0.021	0.617 ± 0.052	0.641 ± 0.054		[43]
Zn (mg/kg)	13.341 ± 0.764	10.684 ± 0.612	1.117 ± 0.064	4.292 ± 0.124	17.650 ± 1.008		[41]
Mn (mg/kg)	6.387 ± 0.097	2.272 ± 0.035	1.307 ± 0.020	0.525 ± 0.008	4.735 ± 0.071		[41]
Macronutrients;							
Ca (mg/kg)	5,541 ± 144	3,671 ± 95	24,760 ± 644	7,661 ± 199	9,121 ± 237	TS 8341:1990 (Ammonium Acetate)	[41]
Mg (mg/kg)	1,108 ± 21	1,073 ± 20	216 ± 4	519 ± 10	1,805 ± 36		[41]
Na (mg/kg)	3,436 ± 98	2,366 ± 68	61 ± 2	320 ± 8	175 ± 5		[41]
K (mg/kg)	713 ± 19	691 ± 18	225 ± 6	1,865 ± 50	1,582 ± 43		[44]

Catalogue [27, 28] excluding remediation projects for the significant contamination, DMs would usually be classified as nonhazardous with a waste code of 17 05 06 (dredging spoil other than 17 05 05) in compliance with AYY [25]. Besides, according to the TS EN 12457-4 (2004) leaching test [29], the leachabilities of DMs were investigated in order to make a decision on the landfill class where DMs could be accepted. In the leaching test, a liquid-to-solid ratio of ten was adopted and Millipore AP40 glass fiber filter was used in order to filter the leachate samples. The concentrations of metals were determined with Perkin-Elmer ICP-OES 8300 DV and ions as F^-, Cl^- and SO_4^{2-} were analyzed in the leachates via Dionex ICS-1000 Ion chromatography. The investigation of organic pollutants such as Benzene, Toluene, Ethyl benzene, Xylene (BTEX) and Polychlorinated Biphenyls (PCBs) were actualized on the solid matrix of DMs. The quantity of Total Dissolved Solids (TDS) was identified by gravimetric method while Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC) were specified with the equipment of TOC-V CPH Shimadzu, respectively. The leachabilities of DMs for the identification of landfill class are pointed out in Table 2 with the limit values given in "ADDDY-Appendix 2: The acceptance criteria of the landfilling of waste" [26]. In compliance with the TS EN 12457-4:2004 leaching test results of DMs, the eluate concentrations of Cl^-, F^-, SO_4^{2-}, TDS, Cu, Mo and Sb were determined in accordance with the limit values of Class II: non-hazardous waste landfill sites. It is known that DMs having high SO_4^{2-}, Cl^- and TDS contents due to the marine (salt) environment are satisfactory [30].

Heavy metal concentrations of the entire DM samples in solid matrix were determined by preparing strong acidic medium (9 mL HNO_3 + 3 mL HCl) via disposing the organic contents in microwave digestion device. At the end of the digestion process, ideal dissolutions were obtained in the liquid phase according to the ISO 11885 standard. Perkin-Elmer ICP-OES 8300 DV was also used for the measurement of heavy metals. The heavy metal parameters were also evaluated in similar studies [31, 32, 33, 34, 35] as well. Heavy metal concentrations of DMs with hazards and risk phrases in the solid matrix are also presented in Table 2. It is observed that all DM samples possess low metal contents that do not cause any risk in environmental manner with respect to the related "AYY-Appendix 3B" [25] hazardous waste threshold limits [36].

Table 4
Compositions of MT samples.

Sample Codes	Mixture Compositions (v/v)
Control-1	Natural soil 33% + Peat 33% + Sheep manure 33%
Control-2	Natural soil 50% + Peat 25% + Sheep manure 25%
Control-3	Natural soil 67% + Peat 16.5% + Sheep manure 16.5%
Mixture-A1	$DM_{Mixture-A}$ (unwashed) 33% + Peat 33% + Sheep manure 33%
Mixture-A2	$DM_{Mixture-A}$ (unwashed) 50% + Peat 25% + Sheep manure 25%
Mixture-A3	$DM_{Mixture-A}$ (unwashed) 67% + Peat 16.5% + Sheep manure 16.5%
Mixture-A4	$DM_{Mixture-A}$ (washed) 33% + Peat 33% + Sheep manure 33%
Mixture-A5	$DM_{Mixture-A}$ (washed) 50% + Peat 25% + Sheep manure 25%
Mixture-A6	$DM_{Mixture-A}$ (washed) 67% + Peat 16.5% + Sheep manure 16.5%
Mixture-B1	$DM_{Mixture-B}$ (unwashed) 33% + Peat 33% + Sheep manure 33%
Mixture-B2	$DM_{Mixture-B}$ (unwashed) 50% + Peat 25% + Sheep manure 25%
Mixture-B3	$DM_{Mixture-B}$ (unwashed) 67% + Peat 16.5% + Sheep manure 16.5%
Mixture-B4	$DM_{Mixture-B}$ (washed) 33% + Peat 33% + Sheep manure 33%
Mixture-B5	$DM_{Mixture-B}$ (washed) 50% + Peat 25% + Sheep manure 25%
Mixture-B6	$DM_{Mixture-B}$ (washed) 67% + Peat 16.5% + Sheep manure 16.5%

2.2.2. Soil quality analysis of topsoil samples' components and MT samples

The entire components of topsoils ($DM_{Mixtures}$, natural soil (Control), peat and sheep manure) and MT samples were dried at 105 °C for the determination of water/solid contents according to TS 9546 EN 12880:2002. Their solid/water contents were measured with PMB 53 Moisture Analyzer. One to five (w/v) aqueous solutions of these dried samples were prepared in order to measure the pH and EC values with WTW Inolab Multimeter. They were incinerated at 550 °C in the muffle furnace in order to identify the organic contents. Bouyoucos hydrometer set was utilized so as to identify the soil textures of samples of concern. In the determination of quantities of available macronutrients (Ca, Mg, Na and K), the entire samples were treated with ammonium acetate extraction solution and filtered through 0.45 μm pore sized filter paper. At the end of the extraction process, aqueous solutions were obtained in compliance with the TS 8341:1990. In addition, micronutrients (Fe, Cu, Zn, Mn, Al) of all samples were taken into the aqueous solution by treating with diethylenetriaminepentaacetic acid (DTPA) with regard to

Table 5
Soil quality analysis results of MT samples (Control and Mixture-A samples).

Parameters	Control-1	Control-2	Control-3	Mix.A1	Mix.A2	Mix.A3	Mix.A4	Mix.A5	Mix.A6	Methods	References for the limit values
Solid content (%w)	75.57 ± 0.99	77.04 ± 1.01	83.07 ± 1.09	61.54 ± 0.81	64.57 ± 0.85	68.46 ± 0.90	51.77 ± 0.68	56.53 ± 0.74	62.74 ± 0.82	TS 9546 EN 12880:2002	-
pH (aq.sol.)	6.40 ± 0.04	6.48 ± 0.04	6.67 ± 0.04	7.41 ± 0.05	7.44 ± 0.05	7.45 ± 0.05	7.41 ± 0.05	7.33 ± 0.05	7.50 ± 0.05	TS ISO 10390:2013	[39]
EC (mS/cm)	2.02 ± 0.04	2.05 ± 0.04	2.16 ± 0.05	4.06 ± 0.09	4.11 ± 0.09	4.98 ± 0.11	2.37 ± 0.05	2.12 ± 0.05	2.23 ± 0.05	TS ISO 11265: 1996	[40]
TOC (g/kg)	139.4 ± 9.1	101.7 ± 6.6	65.3 ± 4.2	141.1 ± 9.2	120.6 ± 7.8	78.0 ± 5.1	139.2 ± 9.0	122.2 ± 7.9	77.5 ± 5.0	TS 8336:1990	-
TN (mg/kg)	5,891 ± 147	3,395 ± 85	2,409 ± 60	4,695 ± 117	2,519 ± 63	1,821 ± 46	6,502 ± 163	3,899 ± 97	1,882 ± 47	TS 8337 ISO 11261:1996	[41]
TP (mg/kg)	1455 ± 39	871 ± 24	643 ± 17	1410 ± 38	1035 ± 28	712 ± 19	1519 ± 41	1078 ± 29	834 ± 23	SM-4500 P	[41]
Organic matter (% w)	32.72 ± 0.22	23.53 ± 0.16	11.82 ± 0.08	14.73 ± 0.10	11.17 ± 0.07	9.08 ± 0.06	14.71 ± 0.10	7.48 ± 0.05	5.12 ± 0.03	TS 8336	[39]
Soil Texture	Sandy Loam	Loamy Sand	Loamy Sand	Sandy Loam	Loamy Sand	Sandy Loam	Sandy Loam	Loamy Sand	Sandy Loam	ASTM D422-63:2007	-
-Sand (%)	67.87 ± 2.19	71.17 ± 2.29	73.35 ± 2.36	74.10 ± 2.39	73.63 ± 2.37	70.06 ± 2.26	73.05 ± 2.35	73.29 ± 2.36	71.51 ± 2.30	Bouyoucos Hydrometer	
-Silt (%)	24.09 ± 0.38	24.85 ± 0.39	23.45 ± 0.37	17.93 ± 0.28	20.04 ± 0.31	25.95 ± 0.41	18.26 ± 0.29	20.32 ± 0.32	24.41 ± 0.38		
-Clay (%)	8.04 ± 0.13	3.98 ± 0.06	3.20 ± 0.05	7.97 ± 0.13	6.33 ± 0.10	3.99 ± 0.06	8.21 ± 0.13	6.39 ± 0.10	4.08 ± 0.06		
Micronutrients;											
Fe (mg/kg)	357.3 ± 5.4	342.2 ± 5.1	306.8 ± 4.6	153.8 ± 2.3	114.6 ± 1.7	91.1 ± 1.4	234.2 ± 3.5	126.6 ± 1.9	110.5 ± 1.7	TS ISO 14870/ T1:2009	[42]
Cu (mg/kg)	0.099 ± 0.008	0.120 ± 0.010	0.164 ± 0.014	5.794 ± 0. 497	6.440 ± 0.552	9.780 ± 0.838	9.286 ± 0.796	7.641 ± 0.655	4.278 ± 0.367	(DTPA Method)	[43]
Zn (mg/kg)	2.42 ± 0.14	1.39 ± 0.08	1.19 ± 0.07	17.17 ± 0.97	14.24 ± 0.81	11.29 ± 0.64	22.45 ± 1.27	13.75 ± 0.78	10.74 ± 0.61		[41]
Mn (mg/kg)	69.84 ± 1.08	111.20 ± 1.71	115.41 ± 1.78	70.72 ± 1.09	36.18 ± 0.56	31.21 ± 0.48	108.30 ± 1.67	48.59 ± 0.75	27.45 ± 0.42		[41]
Macronutrients;											
Ca (mg/kg)	5,898 ± 153	10,570 ± 275	5,395 ± 140	10,060 ± 262	7,764 ± 202	7,403 ± 192	9,880 ± 257	8,888 ± 231	7,834 ± 204	TS 8341:1990 (Ammonium	[41]
Mg (mg/kg)	587 ± 11	882 ± 17	455 ± 9	1,164 ± 22	1,151 ± 22	1,128 ± 21	1,158 ± 22	1,073 ± 20	827 ± 16	Acetate)	[41]
Na (mg/kg)	67 ± 2	169 ± 5	71 ± 2	2,424 ± 69	2,805 ± 80	3,069 ± 87	1,311 ± 37	1,363 ± 39	1,296 ± 37		[41]
K (mg/kg)	615 ± 16	924 ± 25	361 ± 10	1,044 ± 28	867 ± 23	720 ± 19	983 ± 26	757 ± 20	469 ± 13		[44]

TS ISO 14870/T1:2009; then, aqueous solutions were measured via Perkin-Elmer ICP-OES 8300 DV. The contents of TN and total phosphorus (TP) were determined in agreement with the relevant Standard Methods [37]. The quantities of TOC in the samples were identified with TOC-V CPH Shimadzu equipment in conformity with TS 8336:1990 standard.

2.2.3. *Plant nutrient concentrations of grown grass*

Plant nutrient analysis of grown grasses in MT samples was performed. The harvested grass samples were oven-dried at 40 °C until constant weight. Standard methods [37] were used for the determination of phosphorus quantity in grass samples though HACH LANGE 3800 Spectrophotometer. Gerhardt Vapodest 50 Nitrogen Analyzer was used in order to identify the quantity of nitrogen according to the ISO 11261:1996. The sulfur contents of grass samples were specified by using high-temperature tube furnace combustion in accordance with ASTM D 4239. Available macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Fe, Cu, Zn, and Mn) were measured via Perkin-Elmer ICP-OES 8300 DV according to the EPA 3052 standard. 0.20 g dried grass samples were dissolved in a strongly acidic medium (6 mL HNO_3 + 2 mL HCl) by using microwave digestion device (EPA 3052:1996). Then, the solution was diluted to 50 mL. The analysis of all samples were performed by using three replicates and the average values of analysis results were made a present of 95% confidence limits.

3. Results and discussions

3.1. *Soil quality analysis results of each topsoil samples' components*

Soil qualities of each topsoil samples' components together with nutrient analysis results are represented in Table 3. Based upon the topsoil specifications of BS 3882:2015 [12]; it is observed that $DM_{Mixture-A}$, $DM_{Mixture-B}$ and natural soil are situated in "sandy loam" class as soil texture while peat and sheep manure take part in "Clay" class in the texture of soil, respectively. In addition, it is seen that $DM_{Mixture-A}$ is moderately salty (EC = 4–8 mS/cm), $DM_{Mixture-B}$ and peat are slightly salty (EC = 2–4 mS/cm); and natural soil and sheep manure have low EC values [EC = 0–2 mS/cm (salt-free)]. It is a known fact that the signal of EC gives information about the amount of dissolved salts where these salts can cause a decrease in plant germination and growth [38]. Besides, entire $DM_{Mixture}$ samples show strongly alkaline character (pH > 8.50). On the other hand, natural soil and peat have strongly alkaline pH (pH 7.50–8.50) and sheep manure demonstrates neutral pH (pH 6.50–7.50), respectively. The organic contents of all samples are (quite) high (>4%) due to the inclusion of sheep manure except natural soil. It is possible to affirm that the entire topsoil samples' components contain sufficient amounts of macronutrients -especially calcium-so as to go along with plant growth. In general, natural soil is poor with regard to

Table 6
Soil quality analysis results of MT samples (Mixture-B samples).

Parameters	Mix.B1	Mix.B2	Mix.B3	Mix.B4	Mix.B5	Mix.B6	Methods	References for the limit values
Solid content (%w)	66.30 ± 0.87	69.59 ± 0.91	71.85 ± 0.94	69.44 ± 0.91	72.59 ± 0.95	74.82 ± 0.98	TS 9546 EN 12880:2002	-
pH (aq.sol.)	7.46 ± 0.05	7.49 ± 0.05	7.44 ± 0.05	7.48 ± 0.05	7.39 ± 0.05	7.43 ± 0.05	TS ISO 10390:2013	[39]
EC (mS/cm)	4.36 ± 0.10	4.14 ± 0.09	4.62 ± 0.10	2.01 ± 0.04	2.04 ± 0.04	2.03 ± 0.04	TS ISO 11265: 1996	[40]
TOC (g/kg)	139.6 ± 9.1	112.4 ± 7.3	85.2 ± 5.5	139.8 ± 9.1	109.6 ± 7.1	89.1 ± 5.8	TS 8336:1990	-
TN (mg/kg)	5,587 ± 140	3,338 ± 83	2,139 ± 53	4,708 ± 118	3,631 ± 91	2,256 ± 56	TS 8337 ISO 11261:1996	[41]
TP (mg/kg)	1866 ± 50	1319 ± 36	1030 ± 28	1275 ± 34	1172 ± 32	722 ± 19	SM-4500 P	[41]
Organic matter (% w)	19.44 ± 0.13	15.67 ± 0.10	5.97 ± 0.04	18.05 ± 0.12	13.72 ± 0.09	8.31 ± 0.06	TS 8336	[39]
Soil Texture	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand	ASTM D422-63:2007	-
-Sand (%)	85.85 ± 2.76	86.12 ± 2.77	84.72 ± 2.73	85.81 ± 2.76	84.75 ± 2.73	84.73 ± 2.73	Bouyoucos Hydrometer	
-Silt (%)	8.41 ± 0.13	10.89 ± 0.17	8.73 ± 0.14	8.32 ± 0.13	11.07 ± 0.17	8.76 ± 0.14		
-Clay (%)	5.74 ± 0.09	2.99 ± 0.05	6.55 ± 0.10	5.87 ± 0.09	4.18 ± 0.07	6.51 ± 0.10		
Micronutrients;								
Fe (mg/kg)	154.5 ± 2.3	161.5 ± 2.4	111.5 ± 1.7	134.1 ± 2.0	140.5 ± 2.1	184.6 ± 2.8	TS ISO 14870/T1:2009	[42]
Cu (mg/kg)	1.885 ± 0.162	1.736 ± 0.149	1.779 ± 0.152	1.491 ± 0.128	1.719 ± 0.147	2.130 ± 0.183	(DTPA Method)	[43]
Zn (mg/kg)	15.34 ± 0.87	13.97 ± 0.79	12.62 ± 0.72	9.14 ± 0.52	11.65 ± 0.66	12.01 ± 0.68		[41]
Mn (mg/kg)	85.10 ± 1.31	83.65 ± 1.29	60.61 ± 0.93	66.66 ± 1.03	82.67 ± 1.27	94.81 ± 1.46		[41]
Macronutrients;								
Ca (mg/kg)	9,729 ± 253	8,416 ± 219	8,460 ± 220	8,960 ± 233	7,981 ± 208	8,541 ± 222	TS 8341:1990 (Ammonium	[41]
Mg (mg/kg)	856 ± 16	1,023 ± 19	752 ± 14	746 ± 14	678 ± 13	568 ± 11	Acetate)	[41]
Na (mg/kg)	2,031 ± 58	3,913 ± 112	2,659 ± 76	1,120 ± 32	1,181 ± 34	1,379 ± 39		[41]
K (mg/kg)	887 ± 24	857 ± 23	593 ± 16	760 ± 20	558 ± 15	412 ± 11		[44]

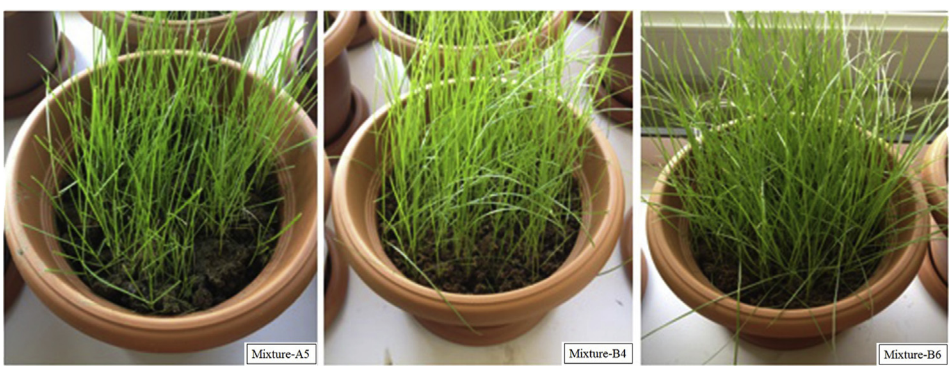

Fig. 3. Grown grasses in Mixture-A5, Mixture-B4 and Mixture-B6 topsoil samples, respectively.

micronutrients. However, the others are rich in terms of micronutrients, particularly in terms of iron. Whereas the amounts of TN are very low in $DM_{Mixture}$ samples; natural soil, peat and sheep manure include high amounts of nitrogen. Besides, TP contents of samples of interest are too high.

3.2. The general estimation of soil qualities of topsoil samples before grass planting

The evaluation of MT samples prepared in different mixing ratios in terms of soil quality before planting of grass seeds has been found appropriate in this paper. Thus, compositions of each fifteen MT chosen with regard to the current landscaping applications in Turkey are demonstrated in Table 4.

Furthermore, the soil quality analysis results of Control, Mixture-A and Mixture-B topsoil samples are pointed out in Table 5 and Table 6, respectively. In pursuance of BS 3882:2015 topsoil specifications [12]; it is understood that MT samples possess “sandy loam” and “loamy sand” soil textures. The MT samples produced with marine DMs (Mixture-A and Mixture-B topsoil samples) have solid content between 61-75% while the solid contents of control samples are found to be between 75-83%, respectively. Besides, pH of control samples are found between 6.40 and 6.70 [slightly (acidic)] and MTs prepared with DMs show neutral pH (pH 7.33–7.50). It is seen that 1^{st}, 2^{nd}, 3^{rd} numbered MT samples prepared by using the raw (without desalination process) $DM_{Mixture}$ samples have some salt content ("moderately salty" EC: 4–8 mS/cm). However, 4^{th}, 5^{th}, 6^{th} numbered MT samples prepared with washed $DM_{Mixture}$ samples have low salt content (“slightly salty” EC: 2–4 mS/cm; “salt-free” EC: 0–2 mS/cm). This salt content of interest was determined to be equivalent with the salt content of Control topsoil samples [38]. It is observed that the entire topsoil samples are rich with regard to available macronutrients and micronutrients. Palleiro et al. (2016) [45] have also identified the same macronutrients (Fe, Mn, Cu, and Zn) in topsoil samples under different land uses so as to assess the mobility and bioavailability of the metals of concern for the environment. The organic matter contents of MT samples are found to be quite “high” (5–32%) due to the presence of

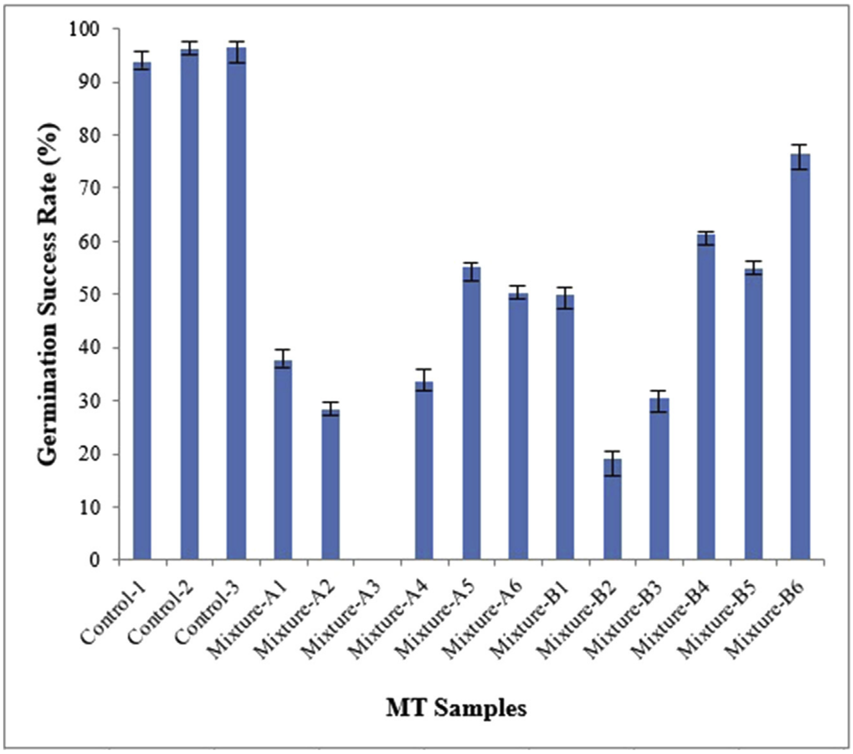

Fig. 4. Germination success rates of all MT samples.

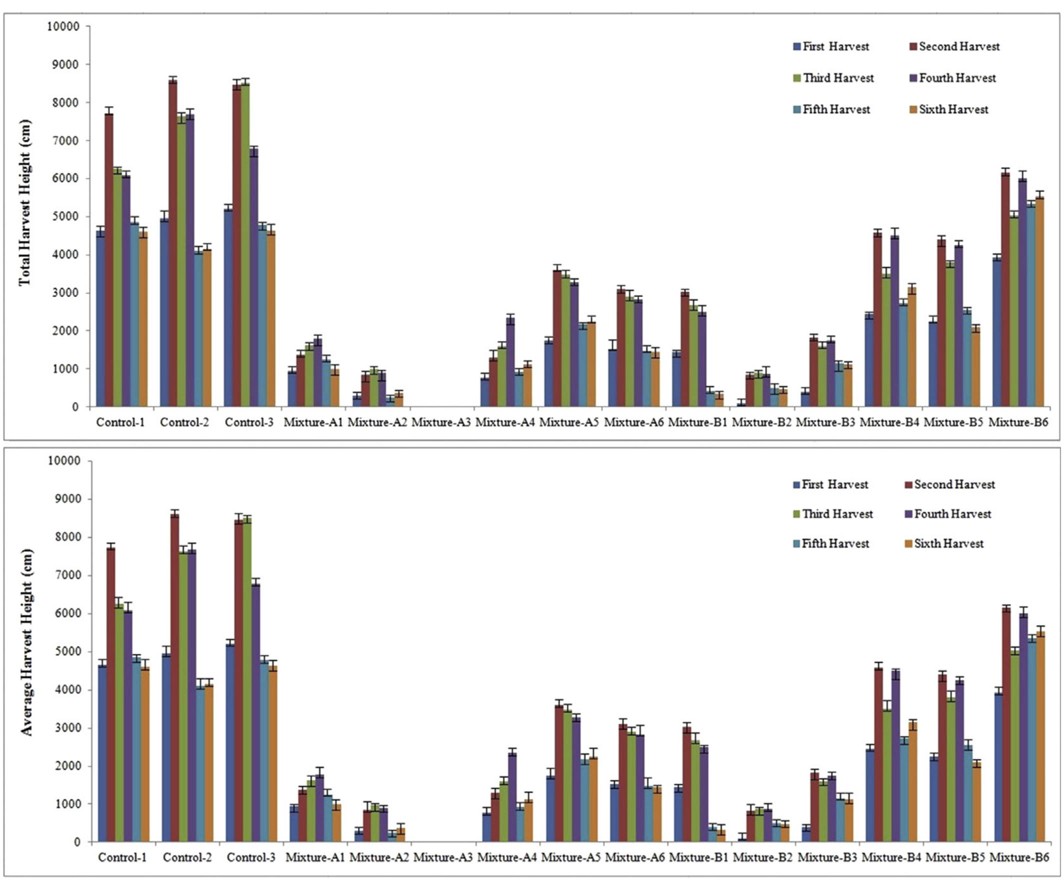

Fig. 5. Average and total height (cm) after each harvest in MT samples.

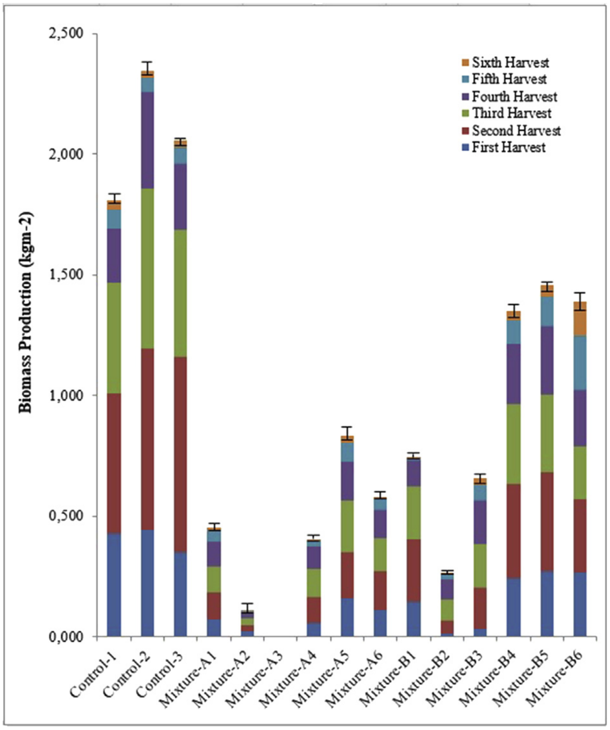

Fig. 6. Biomass production of MT samples.

Table 7
Ranking of grass growth performances in the MT samples.

Sample Codes	Germination Success Rate (%)	Total Growth Height (cm)	Average Growth Height (cm)	Biomass Production (g)	Overall Ranking
Control-1	3	3	4	3	3
Control-2	2	2	3	1	2
Control-3	1	1	2	2	1
Mixture-A1	10	9	12	11	11
Mixture-A2	13	13	14	14	13
Mixture-A3	15	15	15	15	15
Mixture-A4	11	10	10	12	12
Mixture-A5	6	7	7	7	7
Mixture-A6	8	8	8	10	8
Mixture-B1	9	11	11	8	9
Mixture-B2	14	14	13	13	14
Mixture-B3	12	12	9	9	10
Mixture-B4	5	5	6	6	5
Mixture-B5	7	6	5	4	6
Mixture-B6	4	4	1	5	4

sheep manure. On the other hand, it is found that the contents of TN and TP of both control and MT samples are "very high" due to the addition of sheep manure and peat.

3.3. Plant germination trials and the assessment of grass growth performances

Approximately 1.0 g of high quality grass seed was sown 2.5 cm below the surface of soils into each 2 L of plastic pots. The grasses were regularly irrigated at certain intervals with 50 ml of tap water and grass growth performances of the entire MT samples have been daily monitored and recorded. The relevant monitoring parameters were chosen as follows: germination success rate (%), average and total growth height (cm/day) and grass health (visual and by photography), biomass production (kg/m^2), respectively. Grass seed's germination was carried out within 2–3 weeks and grasses were harvested 5 cm above the soil surface monthly. Fig. 3 demonstrates the plant germination trials carried out in this study.

The monitoring of grass growth performances was performed throughout 180-day and a total of six harvests were actualized for each mixture. Average and total harvest height (cm), biomass production (kg/m^2) and the colours of germinated seeds were recorded at each harvest, respectively. The results of germination success rate for all MT samples are shown graphically in Fig. 4.

The colours of grasses were evaluated within the scale ranging from 1 to 5 before each plant harvest; 1: flimsy, light yellow colour, 2: light yellow-green, 3: light green, 4: green and 5: dark green, respectively. In this scale, values 1 and 2 show the deficiency of one or more plant nutrients while value 5 gives information about the excess of plant nutrients, especially nitrogen redundancy. The desired colour for grasses/plants grown in the context of the environmental landscaping is the value of 4 (green). This value also represents the normal growing of grasses/plants and the normal growing of grasses/plants [38]. It is seen that the grasses grown in the entire MT samples have 4 (green) color values.

As it is seen from Fig. 4, control-3 topsoil sample has the highest seed germination success rate of 96.5% as expected. Among twelve MT samples prepared with DM, Mixture-B6 and Mixture-B4 comprising washed DMs have showed better germination rates (76.5% and 61.4%) than those of Mixture-B3 and Mixture-B1 (30.6% and 49.8%) including unwashed DMs, respectively. Considering the Mixture-A series, it is found that Mixture-A5 possess the highest germination rate (55.1%). Besides, it is also observed that MT samples including unwashed DMs such as Mixture-A2 (28.4%) and Mixture-B2 (19.0%) have conducted very low germination rates due to high salinities. On the other hand, no germination was seen in Mixture-A3. Alpaslan et al. [46] also actualized similar study about the examination of salinity effect on the germination rate using the same kind of grass seed. It is known that the existence of salts can cause the enhancement of soil osmotic potential, the reduction of plant growth efficiency, and difficulties for the uptake of nutrients and water from saline soils [7, 47]. These results are also consistent with the Sheehan et al. (2010) research [13].

On the other hand, the total and average heights of grasses in MT samples after each harvest are pointed out in Fig. 5. It is understood that the average and total harvest heights of the entire MT samples increase rapidly in the second and third harvest whereas growth heights start to decrease slowly together with the fourth harvest. Furthermore, it is expected that lower EC values [EC = 0–2 mS/cm (salt-free)] supply more comfortable media for uptake of plant nutrients from the root zone. Thus, MT samples having low EC values (Mixture-A4, B5, A5 and B6) showed higher performances in terms of average and total harvest height. This result is also compatible with the Woodard (2010) outcome [48].

In addition, total biomass productions of entire MT samples presented for a total of six harvests are presented in Fig. 6. It is clearly seen that control samples exhibited quite higher biomass production than those of

Table 8
Nutrient concentrations in the harvested grasses (First, Second, Third harvests).

Parameter	Cont.-1-	Cont.-2-	Cont.-3-	Mix.A1	Mix.A2	Mix.A3	Mix.A4	Mix.A5	Mix.A6	Mix.B1	Mix.B2	Mix.B3	Mix.B4	Mix.B5	Mix.B6	Suff. Range	Ref. for Suff. Range
First Harvest																	
N (%)	3.92 ± 0.09	3.48 ± 0.08	2.57 ± 0.06	2.48 ± 0.06			1.98 ± 0.05	2.65 ± 0.06	2.87 ± 0.07	2.87 ± 0.07			3.14 ± 0.07	3.87 ± 0.09	3.32 ± 0.08	1–5	[49]
P (%)	0.37 ± 0.03	0.28 ± 0.02	0.27 ± 0.02	0.18 ± 0.01			0.17 ± 0.01	0.20 ± 0.02	0.13 ± 0.01	0.19 ± 0.02			0.21 ± 0.02	0.27 ± 0.02	0.33 ± 0.03	0.1–0.5	
K (%)	4.19 ± 0.11	3.94 ± 0.10	3.31 ± 0.09	1.87 ± 0.05			1.85 ± 0.05	1.98 ± 0.05	2.24 ± 0.06	2.10 ± 0.05			2.69 ± 0.07	3.55 ± 0.09	3.16 ± 0.08	2–4	[50]
Ca (%)	1.08 ± 0.07	0.85 ± 0.05	0.82 ± 0.05	0.35 ± 0.02			0.29 ± 0.02	0.38 ± 0.02	0.43 ± 0.03	0.38 ± 0.02			0.58 ± 0.04	0.54 ± 0.03	0.43 ± 0.03	0.4–0.8	
Mg (%)	0.71 ± 0.08	0.60 ± 0.07	0.69 ± 0.08	0.24 ± 0.03			0.26 ± 0.03	0.31 ± 0.04	0.28 ± 0.03	0.32 ± 0.04			0.58 ± 0.07	0.57 ± 0.07	0.55 ± 0.06	0.1–0.4	[49]
S (%)	0.27 ± 0.02	0.28 ± 0.03	0.20 ± 0.02	0.14 ± 0.01			0.15 ± 0.01	0.20 ± 0.02	0.21 ± 0.02	0.19 ± 0.02			0.26 ± 0.02	0.28 ± 0.03	0.26 ± 0.02	0.1–0.4	
Fe (ppm)	144.9 ± 2.6	148.6 ± 2.7	154.7 ± 2.8	136.9 ± 2.5	ND	NH	143.2 ± 2.6	159.6 ± 2.9	168.1 ± 3.0	139.3 ± 2.5	ND	ND	156.2 ± 2.8	169.1 ± 3.1	181.7 ± 3.3	50–250	[50]
Cu (ppm)	11.92 ± 0.19	13.03 ± 0.21	17.19 ± 0.28	14.40 ± 0.23			19.69 ± 0.32	22.40 ± 0.36	21.62 ± 0.35	13.02 ± 0.21			17.83 ± 0.29	20.07 ± 0.33	25.69 ± 0.42	5–20	[49]
Mn (ppm)	147.8 ± 2.2	188.9 ± 2.8	231.3 ± 3.5	90.5 ± 1.4			81.2 ± 1.2	94.2 ± 1.4	96.9 ± 1.5	58.6 ± 0.9			122.5 ± 1.8	113.6 ± 1.7	155.1 ± 2.3	25–300	
Zn (ppm)	45.90 ± 0.74	49.85 ± 0.80	54.47 ± 0.88	69.22 ± 1.11			47.71 ± 0.77	68.32 ± 1.10	76.49 ± 1.23	64.27 ± 1.03			83.42 ± 1.34	79.07 ± 1.27	95.23 ± 1.53	25–150	
N/S Ratio	14.51	12.43	12.85	17.71			13.21	13.40	13.67	15.11			12.08	13.82	12.80	10–15	[51]
N/K Ratio	0.94	0.88	0.78	1.33			1.07	1.34	1.28	1.37			1.17	1.09	1.05	1.2–2.2	
Second Harvest																	
N (%)	4.29 ± 0.10	4.64 ± 0.11	3.35 ± 0.08	3.98 ± 0.09			3.10 ± 0.07	3.37 ± 0.08	3.47 ± 0.08	4.33 ± 0.10		3.57 ± 0.08	4.57 ± 0.11	4.34 ± 0.10	3.06 ± 0.07	1–5	[49]
P (%)	0.43 ± 0.04	0.35 ± 0.03	0.47 ± 0.04	0.30 ± 0.02			0.28 ± 0.02	0.24 ± 0.02	0.19 ± 0.02	0.35 ± 0.03		0.21 ± 0.02	0.31 ± 0.03	0.34 ± 0.03	0.31 ± 0.03	0.1–0.5	
K (%)	4.59 ± 0.12	5.26 ± 0.14	3.87 ± 0.10	3.29 ± 0.09			2.90 ± 0.08	2.69 ± 0.07	3.12 ± 0.08	3.58 ± 0.09		2.75 ± 0.07	3.54 ± 0.09	3.38 ± 0.09	3.67 ± 0.10	2–4	[50]
Ca (%)	1.58 ± 0.10	1.06 ± 0.06	1.09 ± 0.07	0.49 ± 0.03			0.35 ± 0.02	0.44 ± 0.03	0.58 ± 0.04	0.60 ± 0.04		0.33 ± 0.02	0.67 ± 0.04	0.69 ± 0.04	0.77 ± 0.05	0.4–0.8	
Mg (%)	0.78 ± 0.09	0.59 ± 0.07	0.54 ± 0.06	0.36 ± 0.04			0.23 ± 0.03	0.24 ± 0.03	0.33 ± 0.04	0.40 ± 0.05		0.29 ± 0.03	0.57 ± 0.07	0.67 ± 0.08	0.65 ± 0.08	0.1–0.4	[49]
S (%)	0.34 ± 0.03	0.35 ± 0.03	0.29 ± 0.03	0.28 ± 0.03			0.28 ± 0.03	0.30 ± 0.03	0.31 ± 0.03	0.29 ± 0.03		0.23 ± 0.02	0.34 ± 0.03	0.35 ± 0.03	0.28 ± 0.03	0.1–0.4	
Fe (ppm)	201.1 ± 3.6	165.4 ± 3.0	187.6 ± 3.4	171.9 ± 3.1	ND	NH	162.2 ± 2.9	155.6 ± 2.8	207.4 ± 2.8	173.0 ± 3.1	ND	118.5 ± 2.1	203.4 ± 3.7	156.4 ± 2.8	195.9 ± 3.5	50–250	[50]
Cu (ppm)	18.78 ± 0.30	23.28 ± 0.38	17.19 ± 0.28	19.24 ± 0.31			10.78 ± 0.17	15.34 ± 0.25	18.77 ± 0.30	16.98 ± 0.28		14.91 ± 0.24	19.59 ± 0.32	14.68 ± 0.24	17.60 ± 0.29	5–20	[49]
Mn (ppm)	186.7 ± 2.8	263.1 ± 3.9	298.6 ± 4.5	98.1 ± 1.5			88.5 ± 1.3	71.7 ± 1.1	107.5 ± 1.6	70.1 ± 1.1		64.9 ± 1.0	67.6 ± 1.0	71.6 ± 1.1	150.9 ± 2.3	25–300	
Zn (ppm)	65.29 ± 1.05	62.93 ± 1.01	81.61 ± 1.31	75.58 ± 1.22			68.29 ± 1.10	57.08 ± 0.92	91.37 ± 1.47	83.27 ± 1.34		79.53 ± 1.28	106.52 ± 1.71	74.41 ± 1.20	55.34 ± 0.89	25–150	
N/S Ratio	12.62	13.26	11.55	14.21			10.69	11.23	11.19	14.93		15.52	13.44	12.40	10.93	10–15	[51]
N/K Ratio	0.93	0.88	0.87	1.21			1.07	1.25	1.11	1.21		1.30	1.29	1.28	0.83	1.2–2.2	
Third Harvest																	
N (%)	3.89 ± 0.09	4.36 ± 0.10	2.47 ± 0.06	4.04 ± 0.10			3.94 ± 0.09	3.62 ± 0.09	3.62 ± 0.09	4.20 ± 0.10	4.30 ± 0.10	4.21 ± 0.10	4.44 ± 0.11	4.20 ± 0.10	2.91 ± 0.07	1–5	[49]
P (%)	0.38 ± 0.03	0.29 ± 0.02	0.35 ± 0.03	0.29 ± 0.02			0.33 ± 0.03	0.26 ± 0.02	0.16 ± 0.01	0.32 ± 0.03	0.19 ± 0.02	0.24 ± 0.02	0.30 ± 0.02	0.28 ± 0.02	0.30 ± 0.02	0.1–0.5	
K (%)	3.74 ± 0.10	4.23 ± 0.11	2.56 ± 0.07	2.84 ± 0.07			2.91 ± 0.08	2.61 ± 0.07	2.69 ± 0.07	3.25 ± 0.08	2.98 ± 0.08	3.28 ± 0.09	2.69 ± 0.07	3.08 ± 0.08	2.31 ± 0.06	2–4	[50]

(continued on next page)

Table 8 (*continued*)

Parameter	Cont.-1-	Cont.-2-	Cont.-3-	Mix.A1	Mix.A2	Mix.A3	Mix.A4	Mix.A5	Mix.A6	Mix.B1	Mix.B2	Mix.B3	Mix.B4	Mix.B5	Mix.B6	Suff. Range	Ref. for Suff. Range
Ca (%)	1.12 ± 0.07	0.88 ± 0.05	0.65 ± 0.04	0.46 ± 0.03			0.36 ± 0.02	0.41 ± 0.03	0.45 ± 0.03	0.56 ± 0.03	0.54 ± 0.03	0.42 ± 0.03	0.60 ± 0.04	0.48 ± 0.03	0.39 ± 0.02	0.4–0.8	
Mg (%)	0.67 ± 0.08	0.51 ± 0.06	0.31 ± 0.04	0.32 ± 0.04			0.29 ± 0.03	0.29 ± 0.03	0.30 ± 0.04	0.35 ± 0.04	0.36 ± 0.04	0.32 ± 0.04	0.34 ± 0.04	0.33 ± 0.04	0.23 ± 0.03	0.1–0.4	[49]
S (%)	0.34 ± 0.03	0.38 ± 0.03	0.24 ± 0.02	0.27 ± 0.02			0.30 ± 0.03	0.31 ± 0.03	0.34 ± 0.03	0.27 ± 0.02	0.25 ± 0.02	0.27 ± 0.02	0.33 ± 0.03	0.34 ± 0.03	0.28 ± 0.03	0.1–0.4	
Fe (ppm)	157.4 ± 2.8	135.6 ± 2.5	125.4 ± 2.3	163.3 ± 3.0	ND	NH	182.8 ± 3.3	174.9 ± 3.2	180.5 ± 3.3	144.2 ± 2.6	162.8 ± 2.9	124.3 ± 2.2	173.1 ± 3.1	127.5 ± 2.3	151.7 ± 2.7	50–250	[50]
Cu (ppm)	10.84 ± 0.18	17.57 ± 0.28	10.49 ± 0.17	17.38 ± 0.28			13.53 ± 0.22	17.85 ± 0.29	16.48 ± 0.27	15.04 ± 0.24	16.74 ± 0.27	16.26 ± 0.26	14.95 ± 0.24	10.91 ± 0.18	12.96 ± 0.21	5–20	[49]
Mn (ppm)	145.3 ± 2.2	215.2 ± 3.2	265.9 ± 4.0	88.9 ± 1.3			105.9 ± 1.6	79.2 ± 1.2	79.6 ± 1.2	66.3 ± 1.0	75.5 ± 1.1	71.1 ± 1.1	49.2 ± 0.7	53.8 ± 0.8	124.4 ± 1.9	25–300	
Zn (ppm)	50.73 ± 0.82	51.32 ± 0.83	52.52 ± 0.85	86.27 ± 1.39			59.19 ± 0.95	65.72 ± 1.06	80.03 ± 1.29	73.92 ± 1.19	88.73 ± 1.43	92.31 ± 1.49	93.13 ± 1.50	66.38 ± 1.07	43.23 ± 0.70	25–150	
N/S Ratio	11.44	11.47	10.29	14.96			13.13	11.68	10.65	15.56	17.20	15.59	13.45	12.35	10.39	10–15	[51]
N/K Ratio	1.04	1.03	0.96	1.42			1.35	1.39	1.35	1.29	1.44	1.28	1.65	1.36	1.26	1.2–2.2	

ND: Not Determined, NH: Not Harvested

MT samples produced with DMs. Besides, Mixture-B topsoil series possess higher biomass production capacity compared to Mixture-A topsoil series. Regarding the overall evaluation of the harvest performances' results, it is understood that similar results are obtained between the biomass production rates and the total/average harvest heights of MT samples. Total biomass production results for MT samples are also in agreement with the Sheehan et al. (2010) finding [13].

In accordance with the grass growth performances, the efficiency ranking of MT samples was performed by giving equal rates to each performance index of concern. The ranking results of the entire MT samples are summarized in Table 7.

As it can be obviously understood, the efficiency ranking of grass growth performances may be compiled in such a way: Control samples can be ordered as Control-3 > Control-2 > Control-1. The best MT samples are arranged as Mixture-B6 > B4 > B5 > A5 > A6 (containing washed $DM_{Mixture}$) while the worst MT samples are aligned as Mixture-A3 > B2 > A2 (containing unwashed $DM_{Mixture}$). The mixture prescription showed that the most leading grass growth performance is observed in $DM_{Mixture\text{-}B}$ (washed) 67% + peat 16.5% + sheep manure 16.5%. It is clear that MT samples prepared with washed $DM_{Mixture}$ proved better performances than those of MT samples prepared with unwashed $DM_{Mixture}$ with regard to grass germination and growth.

3.4. *Plant nutrient analysis results*

Within the framework of the relevant study, the nutrient analysis results of harvested grasses together with the standard deviations in entire MT samples and the sufficiency range for each parameter are illustrated in Table 8 and Table 9, respectively. Least 0.20 g dried plant (grass) sample is required for the determination of the content of nutrients accurately.

Sufficiency range for the plant growth is defined as the range of quantity of nutrient in order to enhance the growth and nutritional requirements of the plant [52]. As it is illustrated in Table 8 and Table 9, the quantity of macro and micronutrients of harvested grasses have been mostly found within the plant's sufficiency ranges. Nevertheless, there are some exceptions for the quantity of nutrients on harvested grasses where the concentrations of magnesium and calcium, especially in the Control, Mixture-B4, Mixture-B5 and Mixture-B6 samples, are settled above the limit (toxicity range) with regard to sufficiency range. On the other hand, the calcium concentration of grasses harvested from MT samples comprising washed $DM_{Mixture}$ samples is generally higher than those of the calcium concentrations in the grasses of MT samples prepared with unwashed $DM_{Mixture}$ samples. It is clear that the excess of macro-structural elements like calcium leads to the reduction of uptake of micro-structural elements by plant roots required for the plant growth. In addition, it is a well-known fact that nitrogen, phosphorus and potassium are the primary macronutrients that they play a structural role in the plant growth [49]. As it can be seen from Table 8 and Table 9, all harvested grasses involve sufficient amounts of these elements of concern. This result is also consistent with the green color of the harvested grasses where the color of interest is mainly provided by nitrogen and phosphorus elements taken from soil.

Although sulfur concentrations of the harvested grasses were identified within the sufficiency range, N/S ratio, which is higher than 18 [49], implies the sulfur deficiency for grasses grown in the topsoil samples. It is clear that these results demonstrate the successful uptake of sulfur via grasses grown.

3.5. *The general estimation of soil qualities of topsoil samples at the end of the growing season*

At the end of the grass growth period, the soil quality analysis of MT samples taken from 5 cm depth of MT samples situated in 2 L of plastic pots were performed in terms of pH, EC, TOC, TN, TP, available macronutrients. The relevant soil quality testing results with respect to the

Table 9
Nutrient concentrations in the harvested grasses (Fourth, Fifth, Sixth harvests).

Parameter	Cont.-1-	Cont.-2-	Cont.-3-	Mix.A1	Mix.A2	Mix.A3	Mix.A4	Mix.A5	Mix.A6	Mix.B1	Mix.B2	Mix.B3	Mix.B4	Mix.B5	Mix.B6	Suff. Range	Ref. for Suff. Range
Fourth Harvest																	
N (%)	2.73 ± 0.06	3.17 ± 0.08	1.96 ± 0.05	3.96 ± 0.09			3.35 ± 0.08	2.40 ± 0.06	3.67 ± 0.09	2.34 ± 0.06	4.36 ± 0.10	4.01 ± 0.10	3.28 ± 0.08	4.32 ± 0.10	3.74 ± 0.09	1–5	[49]
P (%)	0.24 ± 0.02	0.21 ± 0.02	0.28 ± 0.02	0.36 ± 0.03			0.28 ± 0.02	0.23 ± 0.02	0.18 ± 0.01	0.21 ± 0.02	0.24 ± 0.02	0.27 ± 0.02	0.34 ± 0.03	0.28 ± 0.02	0.30 ± 0.02	0.1–0.5	
K (%)	3.36 ± 0.09	3.66 ± 0.10	3.23 ± 0.08	2.35 ± 0.06			2.81 ± 0.07	2.47 ± 0.06	2.74 ± 0.07	2.36 ± 0.06	3.01 ± 0.08	3.07 ± 0.08	3.53 ± 0.09	3.81 ± 0.10	4.47 ± 0.12	2–4	[50]
Ca (%)	1.00 ± 0.06	0.79 ± 0.05	0.77 ± 0.05	0.48 ± 0.03			0.48 ± 0.03	0.45 ± 0.03	0.48 ± 0.03	0.40 ± 0.02	0.60 ± 0.04	0.42 ± 0.03	0.68 ± 0.04	0.64 ± 0.04	0.71 ± 0.04	0.4–0.8	
Mg (%)	0.45 ± 0.05	0.38 ± 0.04	0.34 ± 0.04	0.36 ± 0.04			0.29 ± 0.03	0.26 ± 0.03	0.30 ± 0.04	0.24 ± 0.03	0.39 ± 0.05	0.34 ± 0.04	0.39 ± 0.05	0.47 ± 0.06	0.54 ± 0.06	0.1–0.4	[49]
S (%)	0.23 ± 0.02	0.29 ± 0.03	0.19 ± 0.02	0.25 ± 0.02			0.24 ± 0.02	0.21 ± 0.02	0.25 ± 0.02	0.16 ± 0.01	0.24 ± 0.02	0.23 ± 0.02	0.29 ± 0.03	0.30 ± 0.03	0.27 ± 0.02	0.1–0.4	
Fe (ppm)	117.4 ± 2.1	108.3 ± 2.0	96.5 ± 1.7	173.3 ± 3.1	ND	NH	169.4 ± 3.1	147.7 ± 2.7	193.6 ± 3.5	94.9 ± 1.7	178.9 ± 3.2	155.8 ± 2.8	171.1 ± 3.1	148.6 ± 2.7	207.8 ± 3.8	50–250	[50]
Cu (ppm)	8.79 ± 0.14	13.50 ± 0.22	10.77 ± 0.17	14.03 ± 0.23			14.55 ± 0.24	15.16 ± 0.25	17.56 ± 0.28	8.74 ± 0.14	11.48 ± 0.19	13.72 ± 0.22	14.89 ± 0.24	18.17 ± 0.29	17.83 ± 0.29	5–20	[49]
Mn (ppm)	98.3 ± 1.5	162.2 ± 2.4	189.8 ± 2.8	94.5 ± 1.4			96.7 ± 1.5	65.9 ± 1.0	78.1 ± 1.2	40.0 ± 0.6	86.2 ± 1.3	78.7 ± 1.2	48.9 ± 0.7	90.2 ± 1.4	139.2 ± 2.1	25–300	
Zn (ppm)	42.77 ± 0.69	47.47 ± 0.76	45.72 ± 0.74	83.81 ± 1.35			74.05 ± 1.19	79.18 ± 1.27	86.60 ± 1.39	68.64 ± 1.11	97.34 ± 1.57	103.12 ± 1.66	94.51 ± 1.52	91.07 ± 1.47	99.75 ± 1.61	25–150	
N/S Ratio	11.87	10.93	10.32	15.84			13.96	11.43	14.68	14.63	18.17	17.43	11.31	14.40	13.85	10–15	[51]
N/K Ratio	0.81	0.87	0.61	1.69			1.19	0.97	1.34	0.99	1.45	1.26	0.93	1.13	0.84	1.2–2.2	
Fifth Harvest																	
N (%)	3.20 ± 0.08	2.79 ± 0.07	3.59 ± 0.09					3.65 ± 0.09	2.71 ± 0.06			2.95 ± 0.07	2.72 ± 0.06	3.23 ± 0.08	4.24 ± 0.10	1–5	[49]
P (%)	0.20 ± 0.02	0.29 ± 0.02	0.27 ± 0.02					0.25 ± 0.02	0.09 ± 0.01			0.20 ± 0.02	0.19 ± 0.02	0.30 ± 0.02	0.18 ± 0.01	0.1–0.5	
K (%)	3.56 ± 0.09	3.17 ± 0.08	3.28 ± 0.09					2.92 ± 0.08	2.37 ± 0.06			2.48 ± 0.06	3.04 ± 0.08	3.60 ± 0.09	4.18 ± 0.11	2–4	[50]
Ca (%)	1.08 ± 0.07	0.96 ± 0.06	1.17 ± 0.07					0.51 ± 0.03	0.48 ± 0.03			0.40 ± 0.02	0.64 ± 0.04	0.56 ± 0.03	0.68 ± 0.04	0.4–0.8	
Mg (%)	0.38 ± 0.04	0.30 ± 0.04	0.28 ± 0.03					0.45 ± 0.05	0.41 ± 0.05			0.35 ± 0.04	0.44 ± 0.05	0.48 ± 0.06	0.54 ± 0.06	0.1–0.4	[49]
S (%)	0.27 ± 0.02	0.25 ± 0.02	0.31 ± 0.03					0.26 ± 0.02	0.22 ± 0.02			0.18 ± 0.02	0.19 ± 0.02	0.24 ± 0.03	0.33	0.1–0.4	
Fe (ppm)	90.1 ± 1.6	74.6 ± 1.4	80.1 ± 1.4	ND	ND	NH	ND	148.4 ± 2.7	132.8 ± 2.4	ND	ND	106.2 ± 1.9	117.5 ± 2.1	101.2 ± 1.8	174.7 ± 3.2	50–250	[50]
Cu (ppm)	6.75 ± 0.11	8.16 ± 0.13	7.54 ± 0.12					17.92 ± 0.29	11.87 ± 0.19			12.71 ± 0.21	10.41 ± 0.17	10.96 ± 0.18	20.24 ± 0.33	5–20	[49]
Mn (ppm)	132.2 ± 2.0	139.7 ± 2.1	163.1 ± 2.4					82.9 ± 1.2	77.7 ± 1.2			79.4 ± 1.2	64.4 ± 1.0	48.8 ± 0.7	157.9 ± 2.4	25–300	
Zn (ppm)	48.23 ± 0.78	44.39 ± 0.71	47.89 ± 0.77					70.70 ± 1.14	72.89 ± 1.17			74.03 ± 1.19	64.39 ± 1.04	66.79 ± 1.08	85.01 ± 1.37	25–150	
N/S Ratio	11.85	11.16	11.58					14.04	12.32			16.39	14.32	13.46	12.85	10–15	[51]
N/K Ratio	0.90	0.88	1.09					1.25	1.14			1.19	0.89	0.89	1.01	1.2–2.2	
Sixth Harvest																	
N (%)	2.54 ± 0.06	2.45 ± 0.06	2.30 ± 0.05					2.79 ± 0.07					2.70 ± 0.06	3.17 ± 0.08	4.48 ± 0.11	1–5	[49]
P (%)	0.26 ± 0.02	0.22 ± 0.02	0.24 ± 0.02					0.27 ± 0.02					0.33 ± 0.03	0.35 ± 0.03	0.43 ± 0.04	0.1–0.5	
K (%)	2.59 ± 0.07	2.58 ± 0.07	2.47 ± 0.06					1.74 ± 0.05					2.41 ± 0.06	2.67 ± 0.07	3.62 ± 0.09	2–4	[50]

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Table 9 (*continued*)

Parameter	Cont.-1-	Cont.-2-	Cont.-3-	Mix.A1	Mix.A2	Mix.A3	Mix.A4	Mix.A5	Mix.A6	Mix.B1	Mix.B2	Mix.B3	Mix.B4	Mix.B5	Mix.B6	Suff. Range	Ref. for Suff. Range
Ca (%)	0.90 ± 0.05	0.80 ± 0.05	0.86 ± 0.05					0.42 ± 0.03					0.62 ± 0.04	0.52 ± 0.03	0.57 ± 0.03	0.4–0.8	
Mg (%)	0.48 ± 0.06	0.54 ± 0.04	0.64 ± 0.08					0.55 ± 0.06					0.61 ± 0.07	0.63 ± 0.07	0.69 ± 0.08	0.1–0.4	[49]
S (%)	0.24 ± 0.02	0.22 ± 0.02	0.22 ± 0.02					0.24 ± 0.02					0.21 ± 0.02	0.24 ± 0.02	0.29 ± 0.03	0.1–0.4	
Fe (ppm)	142.5 ± 2.6	131.8 ± 2.4	128.6 ± 2.3	ND	ND	NH	ND	166.9 ± 3.0	ND	ND	ND	ND	180.5 ± 3.3	177.2 ± 3.2	187.7 ± 3.4	50–250	[50]
Cu (ppm)	13.11 ± 0.21	16.43 ± 0.27	14.95 ± 0.24					15.37 ± 0.25					10.78 ± 0.17	12.41 ± 0.20	13.24 ± 0.21	5–20	[49]
Mn (ppm)	179.4 ± 2.7	218.9 ± 3.3	302.7 ± 4.5					56.6 ± 0.8					81.1 ± 1.2	97.74 ± 1.5	158.5 ± 2.4	25–300	
Zn (ppm)	56.72 ± 0.91	55.39 ± 0.89	62.95 ± 1.01					73.33 ± 1.18					68.74 ± 1.11	84.33 ± 1.36	92.63 ± 1.49	25–150	
N/S Ratio	10.58	11.14	10.45					11.63					12.86	13.21	15.45	10–15	[51]
N/K Ratio	0.98	0.95	0.93					1.60					1.12	1.19	1.24	1.2–2.2	

ND: Not Determined, NH: Not Harvested.

evaluation of topsoil samples at the end of grass growth period are demonstrated in Table 10.

It is realized that Control samples have slightly acidic nature (pH = 6.00–6.50) while pH values of MT samples are found to be in neutral pH range (pH = 7.10–7.50). On the other hand, there is a general decrease in the salt contents of the entire MT samples due to the regular irrigation during plant growth. Furthermore, 1st, 2nd, 3rd numbered MT samples have some salt content ("slightly salty" EC: 2–4 mS/cm) while 4th, 5th, 6th numbered MT samples possess saltless feature with an EC value lower than 2 mS/cm similar to Control samples. As it is seen from Table 10, the contents of TN and TP for both control and MT samples have also demonstrated some decline than those of topsoil samples before grass planting. Nevertheless, their TN and TP contents are "too high" due to the contribution of sheep manure. Besides, the contents of available macronutrients are still quite high compared with measurements performed before plant growth.

4. Conclusions

The following findings were obtained as a result of this study:

- According to TS EN 12457-4:2004 leaching test results, DMs can be disposed at Class II (Non-hazardous waste) landfill due to the eluate concentrations of F^-, Cl^-, SO_4^{2-}, TDS, Mo, Cu and Sb, respectively. Besides, none of DMs exhibited any environmental risk with regard to heavy metal contents in consideration of the hazardous waste threshold limits [25, 36].
- When the soil quality test results are compared before and at the end of the grass growing season, it is found that the contents of available macronutrients at the end of the trials are still as quite high as the nutrient contents of topsoil samples before grass planting.
- Besides, the contents of available macronutrients are still quite high compared with measurements performed before plant growth.
- It is clearly seen that MT samples comprising washed $DM_{Mixture}$ proved better performances than those of MT samples prepared with unwashed $DM_{Mixture}$ with regard to grass germination and growth criteria.
- When the results of plant growth are examined, it can be said that MT samples having loamy sand soil texture are better than those having sandy loam.
- Mixture prescription presenting the finest grass growth performance is stated as $DM_{Mixture\text{-}B}$ (washed) 67% + peat 16.5% + sheep manure 16.5%.
- No substantial variation was observed between Control-3 and Mixture-B6 topsoil samples relevant to the performances of grass growth due to their identical physico-chemical contents.
- In pursuance of the nutrient analysis results of harvested grasses, it is understood that the concentrations of macronutrients and micronutrients of harvested grasses under investigation have been mostly found within the plant's sufficiency ranges with some little exceptions. Concerning the green color of the harvested grasses, it is seen that the grasses indicate a healthy structure in terms of nutrients uptake.
- The results of this study proved that DMs excavated from marine environment can be assessed as topsoil with no detrimental ecological response; nonetheless, various pre-treatment processes in terms of desalination, dewatering, organic amelioration and pH adjustment should be applied on DMs, respectively.
- It can be obviously expressed that 70% ± 5% of DMs can be thought as appropriate for the landscaping applications when taking into consideration the Turkey's fifteen ports/harbors represented in DIP-TAR Project [53]. The relating dredging quantities generated from these coastal regions and their characterization results under investigation and the necessary pre-treatment techniques of interest to be applied, respectively.

Table 10
The soil quality analysis results of MT samples at the end of grass growth period.

Parameters	pH (aq. sol.)	EC (mS/cm)	TOC (g/kg)	TN (mg/kg)	TP (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)	K (mg/kg)
Methods	TS ISO 10390: 2013	TS ISO 11265: 1996	TS 8336: 1990	TS 8337 ISO 11261: 1996	SM-4500 P	TS 8341:1990 (Ammonium Acetate) ICP-OES			
References for the limit values	[39]	[40]	-	[41]					[44]
Control-1	6.32 ± 0.04	1.54 ± 0.03	117.8 ± 7.7	5,185 ± 130	1228 ± 33	4,378 ± 114	327 ± 6	52 ± 2	442 ± 12
Control-2	6.36 ± 0.04	1.71 ± 0.04	80.1 ± 5.2	3,073 ± 77	586 ± 16	6,912 ± 180	505 ± 9	110 ± 4	578 ± 15
Control-3	6.50 ± 0.04	1.83 ± 0.04	51.5 ± 3.4	1,862 ± 47	405 ± 11	8,916 ± 232	589 ± 11	154 ± 5	894 ± 24
Mixture-A1	7.34 ± 0.05	3.57 ± 0.08	123.9± 8.1	4,581 ± 115	1277 ± 34	6,908 ± 180	641 ± 12	1,938 ± 64	720 ± 19
Mixture-A2	7.38 ± 0.05	3.71 ± 0.08	108.9 ± 7.1	3,242 ± 81	984 ± 26	7,248 ± 188	1,096 ± 20	2,847 ± 93	678 ± 18
Mixture-A3	7.37 ± 0.05	4.86 ± 0.11	77.9 ± 5.1	1,804 ± 45	706 ± 19	8,422 ± 219	772 ± 14	678 ± 22	772 ± 21
Mixture-A4	7.33 ± 0.05	2.05 ± 0.04	122.8 ± 8.0	6,106 ± 153	1235 ± 33	7,670 ± 199	851 ± 16	707 ± 23	519 ± 14
Mixture-A5	7.24 ± 0.05	1.84 ± 0.04	103.4 ± 6.7	3,287 ± 82	979 ± 26	6,931 ± 180	720 ± 13	754 ± 25	342 ± 9
Mixture-A6	7.42 ± 0.05	1.96 ± 0.04	65.3 ± 4.2	1,748 ± 44	761 ± 20	5,896 ± 153	410 ± 8	844 ± 28	277 ± 7
Mixture-B1	7.37 ± 0.05	3.86 ± 0.08	126.0 ± 8.2	4,562 ± 114	1,578 ± 42	5,078 ± 132	610 ± 11	1,184 ± 39	707 ± 19
Mixture-B2	7.41 ± 0.05	3.68 ± 0.08	100.9 ± 6.6	3,076 ± 77	1159 ± 31	6,287 ± 163	779 ± 14	2,486 ± 82	694 ± 19
Mixture-B3	7.29 ± 0.05	4.21 ± 0.09	76.9 ± 5.0	1,971 ± 49	947 ± 25	6,094 ± 158	476 ± 9	1,875 ± 62	519 ± 14
Mixture-B4	7.24±0.05	1.57 ± 0.03	117.7 ± 7.7	3,485 ± 87	1709 ± 46	4,577 ± 119	489 ± 9	697 ± 23	620 ± 17
Mixture-B5	7.21 ± 0.05	1.69 ± 0.04	91.4 ± 5.9	3,143 ± 79	1291 ± 34	4,339 ± 113	502 ± 9	525 ± 17	471 ± 13
Mixture-B6	7.14 ± 0.05	1.61 ± 0.04	63.5 ± 4.1	1,431 ± 36	1049 ± 28	4,280 ± 111	336 ± 6	472 ± 15	267 ± 7

Declarations

Author contribution statement

B. Guzel, H. Merve Basar, K. Gunes, S. Yenisoy-Karakas, L. Tolun: Conceived and designed the analysis; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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