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Investigation of Quality Parameters of Soil Sample Collected from Akdağmadeni/Bulgurlu Village District of Yozgat Province

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Abstract: In our study, the chemical composition and soil quality parameters of the soil sample obtained by mixing soil samples taken from 30 cm depth from certain parts of the land at 39°48'20.8"N and 35°53'44.0"E locations of Yozgat/Akdağmadeni Bulgurlu Village in Turkey were investigated. After the soil sample was dried at room temperature, it was sieved with 10 and 60 mesh sieves, respectively. The chemical content of the soil sample was determined by an X-Ray Fluorescence (XRF) Spectroscopy as 40.98% silicon oxide (SiO_2), 13.27% aluminum oxide (Al_2O_3) and 11.04% calcium oxide (CaO). The concentrations of copper (Cu), zinc (Zn), chromium (Cr), manganese (Mn) and lead (Pb) metals in the soil sample were determined by atomic absorption spectroscopy (AAS) using the leaching method by adding nitric acid. The pH, lime, saturation values and the amount of organic, inorganic matter and some elemental of the soil sample were examined. In order to determine the morphological characteristics of the soil sample, color imaging was performed and the soil structure was examined with Stereo microscopy. As a result of the analysis, it was determined that the soil sample was heavy red clay, slightly alkaline, unsalted, calcareous, high in potassium and very low in organic matter and phosphorus. The aim of this study is to contribute to the development of correct fertilization and soil improvement strategies in agricultural practices in the region by determining the soil properties and soil quality of the land.

Yozgat İli Akdağmadeni İlçesi Bulgurlu Köyünden Toplanan Toprak Örneğinin Kalite Parametrelerinin İncelenmesi

Anahtar Kelimeler
Kil,
Toprak analizi,
AAS,
XRF,
Akdağmadeni

Öz: Çalışmamızda, Türkiye'deki Yozgat/Akdağmadeni Bulgurlu Köyünün 39°48'20.8"N ve 35°53'44.0"E konumlarındaki arazinin belirli bölgelerinden 30 cm derinlikten alınan toprak numunelerinin karıştırılması ile elde edilen toprak örneğinin kimyasal bileşimi ve toprak kalite parametrelerinin incelendi. Toprak örneği oda sıcaklığında kurutulduktan sonra sırasıyla 10 ve 60 mesh eleklerle elendi. Toprak örneğinin kimyasal içeriği X-Işını Floresansı (XRF) Spektrometresi ile %40.98 Silisyum oksit (SiO_2), %13.27 alüminyum oksit (Al_2O_3) ve %11.04 kalsiyum oksit (CaO) olarak tespit edildi. Atomik absorpsiyon spektroskopisi (AAS) ile toprak örneğinin içerisindeki bakır (Cu), çinko (Zn), krom (Cr), mangan (Mn) ve kurşun (Pb) metal konsantrasyonları nitrik asit eklenerek liç yöntemi ile tayin edildi. Toprak örneğinin pH, kireç, doygunluk değerleri, organik, inorganik kompanentler ve bazı elementel madde miktarları incelendi. Toprak örneğinin morfolojik özelliklerini belirlemek amacıyla renk ölçümü yapıldı ve stereo mikroskopi ile toprak yapısı incelendi. Analizler soncu toprak örneğinin ağır kırmızı kil, hafif alkalin, tuzsuz, kireçli, yüksek potasyum ve organik madde ile fosfor bakımından çok az olduğu tespit edilmiştir. Bu çalışmanın amacı arazinin toprak özelliklerini ve toprak kalitesini belirleyerek bölgedeki tarımsal uygulamalarda doğru gübreleme ve toprak iyileştirme stratejilerinin geliştirilmesine katkı sağlamaktır.

1. INTRODUCTION

Soil, like a living system, is a natural system with complex and dynamic processes [1]. The minerals, gases, organic matter, microorganisms, and water that sustain these dynamic processes in the soil are its fundamental components [2]. Additionally, it contains essential elements such as carbon (C), oxygen (O), and hydrogen (H), which are crucial for plant nutrition [3]. An ideal soil comprises 45% mineral, 5% organic matter and 50% pores [4].

Soils contain approximately 1 to 6% organic matter [5, 6]. The presence of organic matter in the soil provides essential nutrients for plants, buffers soil pH, increases water retention capacity and enhances soil aeration, thereby improving soil productivity [7, 8]. The frequently changing pH in soil determines some physicochemical and biological processes that sustain soil productivity and plant growth. Macro nutrients (N, P, K, Ca, Mg and S) present in a soil with low pH are less bioavailability than at higher pH levels. The pH of the soil between 6 and 7.5 is ideal for plant growth, but there are some plants that can tolerate, and even prefer more acidic and basic conditions [9-13]. Microelements found in the soil, apart from macroelements, play an important role in plant growth and development. Microelements such as iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl) and nickel (Ni) take part in the regulation of cellular functions in plants. For example, Fe and Zn are critically important in enzyme activity and photosynthesis processes. Mn and Cu play a role in reducing oxidative stress in plant cells, while B is necessary for cell wall formation and pollen development. Mo supports nitrogen metabolism, while Cl is important in ion balance and photosynthesis. Ni is necessary for urea metabolism and enzyme functions. Depending on soil quality, deficiency or excess of these elements can affect plant yield and product quality. Soils with rich organic matter content generally provide an environment where microelements are naturally more accessible. However, increasing agricultural practices and the use of high-yield crop varieties cause microelement deficiencies to become more common. Therefore, proper management of microelements is critical for both plant nutrition and sustainable agricultural practices [14, 15].

The inorganic components of mineral soils are generally sand, silt and clay. The proportion of these different components determines the structure of the soil and its subsequent chemical, physical and biological properties [16, 17]. All these characteristics are important for agriculture. Not all soils are suitable for agriculture; agricultural soils must contain specific proportions of macro and micro nutrients. Ideal soils for agriculture are those in which mineral components (sand: 0.05–2 mm, silt: 0.002–0.05 mm, clay: <0.002 mm), soil organic matter, air and water components are balanced [18, 19]. Soil granule sizes are directly related to soil fertility. The physical structure of the soil affects basic processes such as plant root growth and the movement of water and nutrients. In this case, granule sizes determine the porosity, water holding capacity and air permeability of the soil (Gündüz 2019; Negiş 2020; taş 2022). Soils containing equal amounts of sand, silt and clay are fertile and suitable for agriculture. Soils rich in sand are characterized by their wide pores, enhancing water drainage, yet they cannot retain a significant amount of nutrients in the soil. In contrast, soils rich in clay increase water retention capacity and provide the essential nutrients for many plants [19, 20].

Clay minerals are colloidal structures with a charged surface and high surface area. They are the most reactive inorganic components found in soil [21, 22]. The most common minerals are iron (Fe), aluminum (Al) and manganese (Mn) oxides [23]. Clay soils composed of silicon alumina structures. Additionally, depending on the type of clay, they contain varying amounts of elements such as Scandium (Sc), Chromium (Cr), Copper (Cu), Titanium (Ti), Gallium (Ga), Zirconium (Zr), Manganese (Mn), Magnesium (Mg), Strontium (Sr), and Lead (Pb) [24, 25].

In a study conducted to assess the potential for quince and grape cultivation in the Karanlıkdere Valley of Yozgat Şefaatli district, soil analysis and land use status were examined. Suitability for vineyard and garden investments was assessed and projects on alternative products were developed. As a result, the soils in the region were found to be sufficient in terms of potassium, calcium and iron, but showed deficiencies in nutrients such as nitrogen, phosphorus, magnesium and zinc. The high pH value reduced the usefulness of some nutrients. Zinc fertilization and appropriate fertilization programs are critical to increasing soil fertility [26]. In another study, the relationship between organic matter content, erodibility and some soil properties of the soils where rosehip plants grow in Yozgat province was investigated. Organic matter, macro and micro nutrients, pH, lime, electrical conductivity and erosion factors were analyzed in surface soil samples taken from 30 points. As a result of the study, the soils were generally sufficient in terms of nutrients and the organic matter content varied between 2.28% and 9.87%. Organic matter showed a negative relationship with pH and erosion factor and a positive relationship with Mn and Zn. This situation revealed that organic matter content is important in soil nutrient balance and resistance to erosion [27].

This study investigated the chemical composition and soil quality parameters of the soil samples collected from Bulgurlu Village. To determine the morphological properties of the soil sample, color measurement was performed and the soil structure was examined with stereo microscopy. The chemical components present in the soil samples were determined using XRF analysis. Samples taken from the soil were prepared using the leaching method for the analyses of total Mn, Cr, Pb, Cu, and Zn metals, which were then analyzed using AAS. Soil quality was determined by examining parameters such as pH, saturation, salinity, lime content, phosphate, potassium and organic matter. The aim of this study is to contribute to the development of correct fertilization and soil improvement strategies in agricultural practices in the region by determining the soil properties and soil quality of the land.

2. MATERIAL AND METHOD

2.1. Preparation of Soil Sample

In order to determine the soil quality and to conduct analyses, soil samples were taken from 10 points (every 10 steps) marked at a depth of 30 cm (blue points) in the field land in Figure 1 located at the coordinates of 39°48'20.8"N and 35°53'44.0"E in Bulgurlu Village, Akdağmadeni District, Yozgat Province, Central Anatolia Region of Turkey, in July, and these areas were advanced by drawing zigzags as indicated by Kaçar [28].After the collected samples were mixed homogeneously to represent the general condition of the field, the obtained sample was left to dry at room temperature. The dried soil sample was used for analysis by passing through 10 and 60 mesh sieves, respectively [28, 29, 30].

Figure 1. Google Earth map of the location where the soil sample was taken

In order to determine the morphological properties of the unsieved and sieved soil, color measurement was performed with a Konica Minolta device and the soil structure was examined with LEICA S6 D Stereo microscopy [31].

2.2. XRF Analysis

To calculate the loss on ignition (LOI) of the finely powdered soil sample, it was dried in the incubator at 105 °C for 2 h. The empty crucible was weighed and kept in the muffle furnace at a rate of 10 °C min^{-1} to 1050 °C for 1 hour. It was then cooled in a desiccator and weighed again. These processes were repeated until the crucibles reached a stable weight. Subsequently, 1 g of clay sample was added to the crucible that had reached constant weight and was placed back in the muffle furnace at 1050 °C [32]. After cooling in a desiccator and weighing, the loss on ignition was calculated according to the equality 1 below;

$$\frac{(M_2)-(M_3)}{(M_2)-(M_1)}\%100 = LOI \qquad (1)$$

$M_1 = mass\ of\ the\ empty\ crucible\,(g)$

$M_2 = mass\ of\ the\ empyt\ crucible + dried\ sample\,(g)$

$M_3 = mass\ of\ the\ empyt\ crucible + ignited\ sample\,(g)$

For XRF analysis, lithium tetraborate was added to the soil sample whose ignition loss was calculated and glassy pellet was obtained with the fusion device. The elemental composition of the prepared sample was determined by XRF spectroscopy using Panalytical Axios Max minerals equipment.

2.3. Heavy Metal Analysis

For AAS analysis, unsieved and sieved soil samples were prepared using the leaching method. 1 gram of each unsieved and sieved soil sample was weighed, and 200 ml of nitric acid (Reagent pure, 65%) was added. The acidified soil samples were shaken at 400 rpm at room temperature for 2, 3, and 12 hours. After shaking, the soil samples were allowed to settle at room temperature to enable the soil particles to precipitate to the bottom of the flask [33, 34]. The supernatant liquids were then taken and diluted to specific ratios. Calibration curves, prepared standard compounds of Mn, Cu, Cr, Zn and Pb were created in detail and AAS analysis of soil samples was developed with Perkin Elmer / Elmer Analyst 800 device.

2.4. Soil Quality Parameter Analysis

The raw soil sample was sieved using the dry sieving method and pH, phosphorus, potassium, saturation, salt content, lime percentage and organic matter percentage were determined in accordance with standard methods. In order to determine the water holding capacity of the soil sample, experiments were carried out with air-dry soil in accordance with the Turkish Standard TS 8333. pH measurement was made using the method suggested by Yurdakul to determine the acidity or alkalinity level of the soil. For the lime content in the soil, TS EN ISO 10693 standard was modified and the amount of salt in the soil was determined by measuring the electrical conductivity in samples turned into mud according to the TS 8334 standard. The available soil phosphorus content that can be taken by plants was also measured according to the Olsen method. This method was determined by extracting phosphorus with sodium bicarbonate and measuring its concentration spectrophotometrically. The organic matter content of the soil was determined by measuring the amount of available potassium according to the TS 8336 standard and its concentration according to the TS 8341 standard [28, 35-37].

3. RESULTS

Sieved and unsieved soil samples were examined under a stereo microscope (**Figure 2)**. In the stereo microscopy analysis of the soil samples, there is an almost homogeneous image in the sieved soil sample in **Figure 2B**, while the particle sizes of the unsieved soil are in different distributions in **Figure 2A** [38,39].

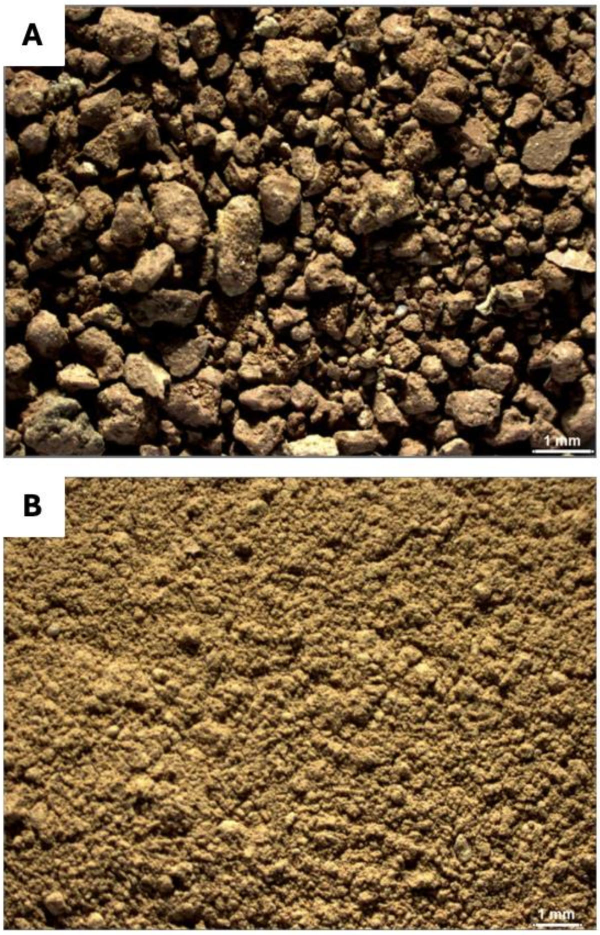

Figure 2. Stereo microscopy analysis **A)** unsieved soil sample B) sieved soil sample

Colour measurements of sieved and unsieved soil samples were analysed according to the absolute colour system L*, a* and b*' method (L* = brightness], a* = green-red and b* = yellow-blue) [40]. Color measurement values of sieved and unsieved soil samples are given in **Table 1.**

Table 1. Colour measurement values of sieved and unsieved soil samples

Colour parameters	Unsieved soil	Sieved soil
L	58.7	63.1
a	13.3	16.6
b	34.2	42.5

The chemical composition of the clay was determined by X-Ray Fluorescence Spectroscopy using Panalytical Axios Max Minerals equipment. The finely powdered clay sample was mixed with lithium tetraborate for chemical analysis and the LOI was calculated as 21.84% by calcination at 1000°C. The results of the XRF analysis performed to determine the chemical composition of the minerals present in the soil sample are given in **Table 2.** It is observed that the majority of the soil sample consists of SiO_2, Al_2O_3 and CaO, respectively.

Table 2. XRF results of clay sample

Compound Name	Concentration (unit)	Absolute Error (unit)
SiO_2	40.98%	0.1%
Al_2O_3	13.27%	0.1%
CaO	11.04%	0.09%
Fe_2O_3	5.385%	0.07%
MgO	4.232%	0.06%
K_2O	1.749%	0.04%
TiO_2	0.4752%	0.02%
Na_2O	0.4270%	0.02%
P_2O_5	0.1653%	0.01%
SO_3	0.1133%	0.01%
MnO	917.4 mg kg^{-1}	90 mg kg^{-1}
Cl	900.9 mg kg^{-1}	90 mg kg^{-1}
SrO3	450.7 mg kg^{-1}	60 mg kg^{-1}
Cr_2O_3	399 mg kg^{-1}	60 mg kg^{-1}
NiO	285.2 mg kg^{-1}	50 mg kg^{-1}
CuO	170.6 mg kg^{-1}	40 mg kg^{-1}
ZnO	108.6 mg kg^{-1}	30 mg kg^{-1}

Common heavy metals contained in 6 soil samples prepared by the leaching method using AAS spectroscopy are given in **Table 3**. According to the results, metals were mostly detected better in samples treated with acid for 12 hours compared to those treated for 2 and 3 hours [41, 42]. When comparing the AAS analysis results of raw and sieved soil samples, similar metal values were detected in both samples. The highest Mn and the lowest Cr metal were found in both raw and sieved soil sample.

Table 3. Concentration of certain metals in the soil sample (mg kg^{-1})

Sample	Mn	Pb	Cu	Cr	Zn
Raw soil 2 h	73.9± 0.017	3.320±0. 038	4.940± 0.009	-	6.350±0 .013
Raw soil 3 h	71.55± 0.013	4.040±0. 163	5.12±0. 06	-	6.480±0 .015
Raw soil 12 h	92.55± 0.008	4.750±0. 027	5.26±0. 032	-	5.930±0 .005
Sifted soil 2 h	79.050 ±0.01	3.670±0. 062	5.77±0. 005	-	6.650 ± 0.013
Sifted soil 3 h	87.1±0. 008	2.720±0. 043	4.380± 0.017	2.630± 0.200	6.840 ± 0.029
Sifted soil 12 h	92.700 ±0.01	3.09± 0.053	5.310± 0.011	4.750± 0.412	6.340± 0.011

As a result of the experiment conducted on the soil sample, it is shown in **Table 4** that the soil is alkaline, calcareous, salt-free and clay in structure, and that phosphate and potassium, which are macro nutrients, are present in the soil sample, albeit in small amounts. In this case, it is seen that the soil sample is in clay form as a result of both XRF and soil analysis. As a result of the analysis, it was determined that the soil sample had a heavy red clay structure, was slightly alkaline, salt-free, calcareous, had high air content, and had very low organic matter and phosphorus content. The analysis results of your soil show that the current plant characteristics are not suitable in some ways, but can be improved.

Table 4. Soil quality parameters

Analysis name	Result	Assessment
Saturation	140.15	Heavy clay
pH	8.25	Slightly alkaline
Lime%	20.76	Highly calcareous
Salt%	0.042	Saltless
FOSFAT (P_2O_5) kg da^{-1}	1.72	low
Organic matter%	0.63	low
POTASSIUM (K_2O) kg da^{-1}	54.6	Hight

4. DISCUSSION AND CONCLUSION

According to the XRF analysis of the soil sample, the main component of the soil sample is found to be 40.98% SiO_2. Additionally, the soil sample contains 13.27% Al_2O_3 and 11.04% CaO. Upon examining the soil color, it is observed that the color of the soil is red. Clays consist of alumina silica structures. The red color of red clay is attributed to the presence of iron within it [12, 13]. Consequently, these components indicate that the sample is red clay.

Soil fertility is determined based on certain parameters, including micro and macro elements, saturation, salt content, pH, and organic matter. Micro and macro (nitrogen, phosphorus, potassium, etc.) elements play an crucial role in plant nutrition. Micro elements are found in lower amounts in soil compared to macro elements. Microelements such as nickel, boron, zinc, chromium, manganese, copper, chlorine and iron are sufficient to be present in the soil even at low concentrations for plant development [1, 4, 5]. AAS analysis was conducted to examine the total Mn, Cu, Cr, Zn, and Pb metal contents of the soil sample. Mn metal was detected in the highest amount of 92.7 mg kg^{-1} in the sieved clay treated with acid for 12 hours, while Cu, Pb and Zn were detected in similar proportions in six samples. However, while Cr metal was not detected in raw clay samples, it was detected in trace amounts in sieved clay samples treated with acid for 3 and 12 hours. This variation can be attributed to the different durations of treatment with nitric acid for AAS analysis.

Heavy clay was found as a result of the saturation level of the soil sample. Compared to sandy soils, clayey soils have a higher water retention capacity. Soils with high water retention capacity enable plant roots to penetrate deeper into the soil, thus affecting soil fertility [43, 44]. Upon examination of the soil sample for salt content, it was evaluated as salt-free. In soils with high salt concentrations, it reduces the permeability of water and accelerates its evaporation. This situation causes the vegetation to become weak and spindly [44]. The fact that our soil sample has a low salt content and a high water retention capacity will ensure that the products that can be grown on it will be productive. Soils have a pH between 0 and 14, depending on their composition. Plants generally thrive in pH ranges between 5.5 and 6.5. Each soil has unique pH value, determining the type of plant species grown. The pH value of our soil sample was found to be 8.25 slightly alkaline. Organic substances in soil are formed as a result of the decomposition of animals and plants residues by bacteria in the soil. Fertile soil should contain an average of 5% organic matter [5, 43]. The organic matter content of our soil sample was found to be low at 0.63%. The very low organic matter content in our soil sample prevents the agricultural plants on it from developing as a result of malnutrition. This issue can be addressed by fertilizing the soil with barn manure.

Phosphorus (P) and potassium (K) are two essential elements that complement each other but have different functions in plant growth and development. Phosphorus plays a central role in energy production and transfer and is necessary for vital processes such as photosynthesis, respiration, DNA and RNA synthesis. Plants usually take phosphorus in the form of phosphate ($H_2PO_4^-$ or HPO_4^{2-}), which is obtained from organic matter or phosphate minerals found in soluble form in the soil. Phosphorus has critical effects such as promoting root development and supporting early plant growth processes. Potassium regulates cellular water balance, supports enzyme activities and controls the opening and closing mechanisms of stomata. These properties increase the resistance of plants to water stress and diseases. In addition, potassium supports fruit and seed development and increases product quality. Phosphorus is especially effective in the early growth period, while potassium is more critical in the maturity and stress management processes of the plant. Both elements are necessary for optimum plant growth and their balanced presence in soil is vital for plant development. Regular soil analysis for these elements and use of appropriate fertilization methods are critical steps for sustainable agriculture and productivity. Potassium and phosphate are essential macro-nutrients for plant growth, root resilience, and increased water retention capacity [43-46]. Total phosphate amount of our soil sample was found to be very low at 1.74 kg da^{-1}, while the potassium amount was found to be high at 54.6 kg da^{-1} [47] Our soil sample contains a high amount of lime at 20.76%. This situation is caused by the calcium carbonate ($CaCO_3$) contained in the soil. Calcium ions (Ca^{+2}) are necessary for plant nutrition and increasing soil granulation. Ca^{+2} ions contribute to the soil to yield more crops and control soil pH [47, 48].

In a study conducted to evaluate the soil fertility in Turkiye, it was found that the soil structure throughout Turkiye is generally sandy-clayey loam, non-saline, slightly alkaline, lime and low in organic matter. Additionally, it was determined that the total P content is low while K is high [48-51]. Analysis of our soil sample revealed that the soil structure is heavy clayey, non-saline, highly lime, with high potassium content, and deficient in organic matter and phosphate. The high content of silicon dioxide and aluminum oxide, as indicated by XRF analysis, supports its clayey structure, while the presence of significant amounts of calcium oxide reinforces its calcareous nature. Additionally, AAS analysis identified some of the micro-nutrient metals present in the soil.

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