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Effect of Long Term Storage of Soil Sample on Some Chemical Properties of Vertisol and Andosol at Kulumsa Agricultural Sub Centers

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ABSTRACT

The present study was conducted at the Kulumsa Soil and Plant Analysis Laboratory, Ethiopia from January 2021 to January 2022 to identify the appropriate storage duration of soil samples and recommend good storage materials for soil laboratories. The effects of soil sample storage on the pH, TN (%), OC (%), and available phosphorus were studied for 12 months. The highest and lowest concentrations of pH, TN (%), OC (%), and available phosphorus at the Kulumsa site were: 6.29 and 5.82; 0.17 and 0.12%; 2.93 and 1.70%; 22.53 and 10.88 respectively. At the Arsi Robe site, the highest and lowest concentrations of pH, TN (%), OC (%), and available phosphorus were 6.54 and 5.97, 0.16 and 0.12%, 3.02 and 1.00%, and 19.09 and 10.39 respectively. The highest and lowest concentrations of pH, TN (%), OC (%), and available phosphorus (mg kg1) at the Dera site were 9.14 and 8.47; 0.11, 0.07%; 4.36, 1.04%; and 111.85 and 75.37 respectively. Soil samples were stored in three storage containers with replications. The storage materials a card box with a plastic bag and a polyethylene bottle have not made any significant difference in the results of a soil sample stored under laboratory. A card box with a plastic bag was the appropriate material for soil sample storage for long-term analysis. However, based on the cost effectiveness and availability of the material to be purchased for the soil storage condition, the polyethylene plastic bag was the best option for soil sample storage under laboratory conditions.

KEYWORDS: Available phosphorus, carbon, nitrogen, pH, phosphorus, soil, storage

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

The effect of long term soil sample storage on soil chemical properties being studied is an important issue that needs to be considered before planning an experiment. Although research suggests that soil samples should be analyzed immediately after sampling (Zelles et al., 1991; Mihiretu, 2020**)**. In such cases, soil samples are commonly air-dried for storage (McDowell et al., 2006) or frozen-stored at -20°C or lower in a freezer (Erhagen et al., 2013; Zhao et al., 2008; Petersen and Klug, 1994).

A common method to preserve soil samples for future analyses has been to store them air-dried in plastic bags in unheated storage rooms (Haynes and Swift, 1985). This will probably bring some fluctuations in soil moisture during storage and temperature may vary the result of data substantially (Stenberg et al., 1998; Lee et al., 2007). There is a little bit knowledge on effects of time and storage conditions on some soil chemical properties of the soil as most studies have been made on drying effects over short periods, from a few days to some weeks, while the actual storage time may be several years (Marti et al., 2012; Zhao et al., 2012). The mineralization of nitrogen and carbon increases (Ross et al., 2001; Gerenfes et al., 2022), possibly because of the breaking of hydrogen bonds within the soil organic matter and increased microbial activity.

The effect of storage time, studied over 16 weak, was a continuous change towards an increase in surface acidity, exchangeable Mn, solubility and oxidizability of organic matter (Bartlett and James, 1980; Mihiretu, 2020). The pH usually decreased as an immediate effect of drying and then continued to decrease over a period of 4–12 months. The decrease was most pronounced during the first two months for pH (H_20) while changes in pH ($CaCl_2$) were small (Daveyand Conyers, 1988).

A higher drying temperature seems to emphasize these effects (Mihiretu, 2020). In some peat soils, extractable Fe (NH_4Ac-EDTA) decreased with higher temperature while P (NH_4Ac) increased and changes in other nutrient concentrations were negligible (Payne and Rechcigl, 1989; Shuman, 1980; Codling and Eton, 2014; Ross et al., 2001; Saarinen, 1989). Sample storage methods may influence both the physico-chemical, and biological properties of soils. Air-drying has been reported to decrease soil pH and increase extractable Mn, Fe, Cu and Zn contents (Codling and Eton, 2014; Ross et al., 2001). Although frozen storage at -20°C may also change some of the microbial properties, its effects are generally more moderate as compared to that caused by air-drying (Schutter and Dick, 2000). However, different sample storage methods including air-drying and frozen storage are commonly used prior to sample analysis (Jones and Willett, 2006; Kaiser et al., 2001). These sample storage methods might influence the concentration and chemical property of soil. As a result, comparison between studies using different sample storage methods can be difficult. Although sample storage methods may influence both the physico-chemical-biological properties of soils (Raveh and Avnimelech, 1978; VanGestel et al., 1993).

According to Laura (1975) drying would result in the breakdown of organic matter. Air-drying of soil samples has been found to enhance the mineralization of organic matter as air-drying increases the solubilisation of organic matter and disrupts soil aggregates. This study was thus, conducted with in the following objectives: (i) to identify the effect of storage condition of soil sample (ii) to select appropriate soil storage materials. In summary, the present study aimed to generate base line information on repeated chemical analyses of pH, %TN, OC, and av. p, storage material and duration of vertisol and andosol soil sample has been stored in laboratory.

2. MATERIALS AND METHODS

2.1. Description of the study area

The study was carried out under laboratory condition from January 2021 to January 2022 at Kulumsa Soil and Plant Analysis Laboratory, Ethiopia. To obtain a set of soils representing a range of soil types and properties, soil samples were collected from three sites representing two dominant agroecology. Site one (07°08'32.6" N and 039°62'58.6" E) had an agricultural and livestock production system located near Arsi Robe town in Eastern Assela, Arsi. The soil type is heavy clay soil with a waterlogged vertisols of 2326m above mean sea level based on data collected during soil sample collection. Site two (08°19'01.8"N and 039°19'05.6" E) was an andosol belt system located near Dodota town in north central Assela, Arsi. The soil was silty loam soil (andosol) with a drought prone agroecology having 1681 m above sea level based on data collected during study time. Site three Kulumsa Agricultural Research Center (KARC) is located in Oromia National Regional State, Arsi Administrative Zone. It is at about 175 km south of Addis Ababa. Its geographical extent is from 08°01'08.6" northern latitude and 039°09'11.6" eastern longitude. The soil type was clay soil (Luvisols) and the soil texture was clay having mid-altitude of 2170m above sea level. The soil samples were collected from Arsi Robe and Kulumsa (clay soil which has vertic properties) and Dera sub centers (andosol) of Kulumsa agricultural sub centers. The soil sample storage materials were plastic bag, plastic bag with carton, and polyethylene bottle. Each material was done with three replications for each location. The first analysis was made within two months of sampling. Determination of pH, TN, OC and available P was repeated with four, six, eight, ten and twelve months starting from sample collection.

2.2. Soil sample collection and preparation

The soil sample were collected from three sub centers of Kulumsa Agricultural Research Centers. Twenty one composite soil samples were collected from the depth of (0–20 cm) using soil auger systematic sampling technique method from each sub centers. Soil samples taken from areas were separately labeled and transferred into air tight polythene bags and brought to Kulumsa research center for laboratory analysis. The collected soil samples were air dried grinded with a mortar and pestle and passed through a 2 mm mesh sieve to remove coarse particles and stored at room temperature prior to analysis. The composite soil samples were divided in to soil sample storage materials such as plastic bag, plastic bag with carton, and polyethylene bottle.

2.3. Determination chemical parameters of the soil samples

Soil samples were analyzed for the following chemical parameters such as pH, total nitrogen, organic carbon, and available phosphorus at the soil and plant laboratory of Kulumsa Agricultural Research Center. The pH of the soil was determined by using potentiometric method at 1:2.5 (w/v) soil to water ratio using a glass electrode attached to digital pH meter (Thomas, 1996). The pH meter (HI9017, HANNA) was calibrated using standard buffer solution of pH 4.0 and 7.0. Then electrode of the pH meter was inserted in to the supernatant solution and the pH reading was taken. The total nitrogen content was determined using Kjeldahl method as described by (He et al., 1990). Available phosphorus was determined by using the Bray II extraction method (Bray, 1954). Soil organic carbon was determined by routine Walkely-Black dichromate method (Hessen, 1971). The results were usually quoted as the percentage by weight of organic carbon in the soil.

2.4. Data analysis

All the results of analysis were reported as mean of triplicate measurements. The data was computed using SAS statistic for nutrient analysis. The recorded data was subjected to analysis of variance (ANOVA), to assess the effect of soil sample storage on pH, total nitrogen, organic carbon and available phosphorus. The interaction between soil sample storage time and materials also seen. Two-way ANOVA was used to test the existence of significant difference between means. In all statistical analyses, confidence level was held at $p>0.05$.

3. RESULTS AND DISCUSSION

3.1. Soil chemical properties

The chemical parameters analyzed for the soil samples collected from three sites varied among the sites (Table 1). The highest and lowest average concentrations of soil reaction (pH), total nitrogen (%TN), organic carbon (% OC), and available phosphorus (Av.P) at the Kulumsa site were 6.29 to 5.82 pH; 0.17 to 0.12% TN; 2.93 to 1.70% OC; and 22.53 to 10.88 available phosphorus (mg kg^{-1}), respectively. The chemical parameters were categorized as moderately to slightly acidic by soil reaction, medium to high by total nitrogen, moderate in organic, and low to medium in the case of available phosphorus, respectively. The results of chemical parameters at the Dera site were 9.16 to 8.47 pH; 0.11 to 0.07 %TN; 4.36 to 1.04% OC; and 111.85 to 75.37 available phosphorus (mg kg^{-1}), respectively. The chemical analysis of each parameter was categorized under alkaline to strongly alkaline conditions by soil reaction (Tekalign, 1991), the total nitrogen was categorized as low to medium, the organic carbon content was categorized as low to high (Tekalign, 1991), and given the values of available phosphorus, it was categorized as high (Jones and Willett, 2006) at the Dera site. The results of the chemical parameters at the Arsi Robe site were 6.54 to 5.97 pH; 0.17 to 0.12% TN; 3.02 to 1.13% OC; and 19.09 to 10.39 available phosphorus (mg kg^{-1}) respectively. The chemical analysis of parameters was categorized as moderately to neutrally neutral by soil reaction (Tekalign, 1991), the total nitrogen was categorized as medium to high, the organic carbon content was categorized as low to medium (Tekalign, 1991), and given the values of available phosphorus, it was categorized as low to medium (Jones and Willett, 2006). The results of andosol (Dera site) has been high with soil reaction, low content of total nitrogen, and high content of available phosphorus compared to vertisol area as shown in Table 1 below. The average mean concentration of the chemical analyses of vertisol and andosol soils that were performed for the soil samples from three sites is presented in Table 1 below.

Table 1: Chemical properties of the soils of the experimental sites

Sl. No.	Locations	pH	Total N (%)	Organic carbon (%)	Available P (mg kg^{-1})
1.	Kulumsa	6.06	0.15	2.32	16.71
2.	Dera	8.82	0.09	2.70	93.61
3.	Arsi Robe	6.26	0.14	2.08	14.74

Note: N and P are nitrogen and phosphorus, respectively

The chemical analyses of vertisol and andosol soils were performed for the soil samples from three sites are presented in figures 1, 2, 3, and 4.

3.2. Effect of long term soil sample storage on soil pH

The soil samples collected from both soil types were stored for one year to identify the long-term effect of soil sample storage conditions. Based on this assumption, as shown in Figure 1, the pH of the soil sample stored for one year was

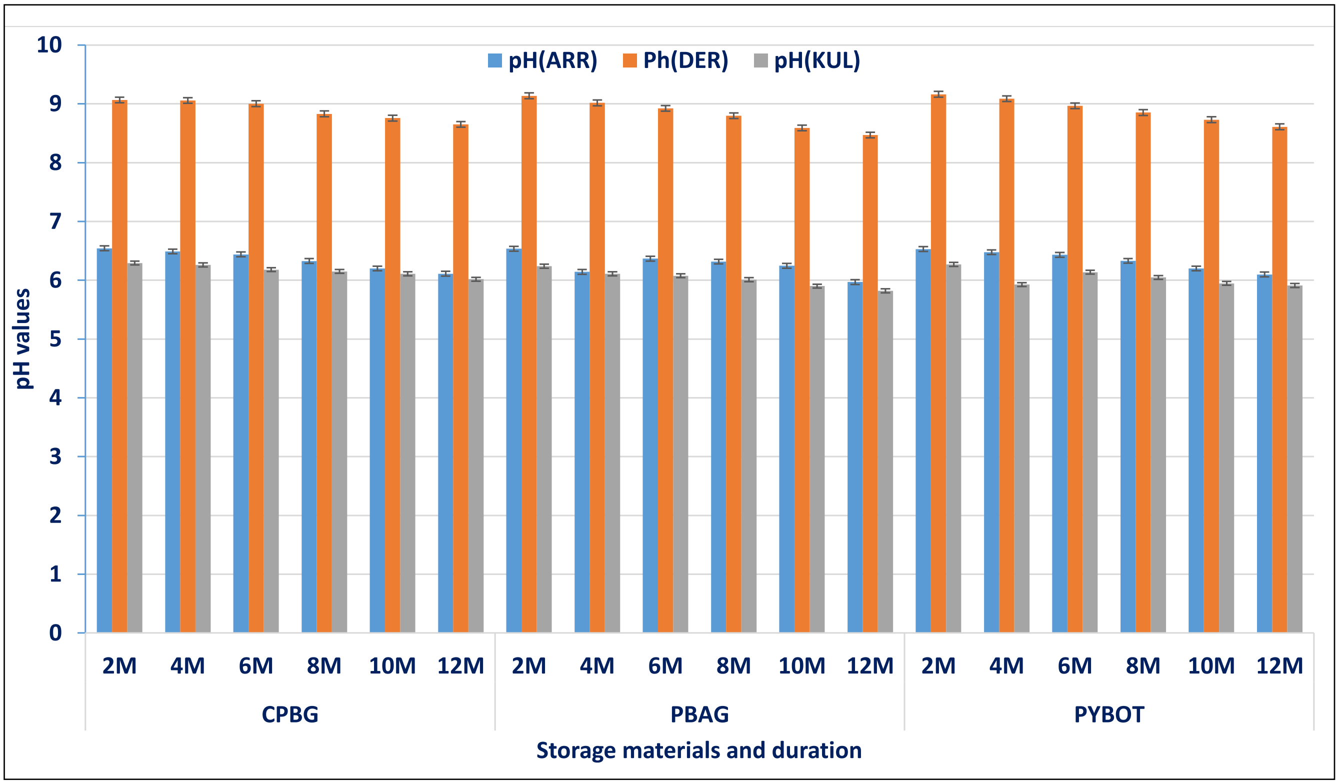

Figure 1: Effect of storage time on soil pH; Where, CPBG: Card box with plastic bag; PBAG: Plastic bag, PYBOT: Polytelene bottle; ARR: Arsi Robe; DER: Dera; KUL: Kulumsa; M: Months

analyzed six times within two-month intervals. The pH of vertisol and andosol decreased gradually over time during the twelve months. The highest average concentration of pH was obtained at the 2nd month, and the lowest average concentration was achieved at the 12th month in vertisol and andosol types of soil samples collected from the study sites. This result indicated that the mean concentration of pH was reduced from month 2 to month 12, which is in agreement with the reports by (Bartlett and James, 1980; Mihiretu, 2021). In line with the current results, Lee et al. (2007) reported some fluctuations in soil moisture during storage, and that temperature may vary the result of the data substantially. Soulides and Allison (1961) observed that air-drying has been reported to decrease soil pH and increase extractable Mn, Fe, Cu, and Zn contents, and is considered to be the worst storage method if soil biological properties are to be studied on those stored samples, as it may cause the death of some bacteria because of hydric stress caused by the osmotic effects of the drying process. Agreeing with the current results, a significant reduction in soil pH of vertsol from the initial analyses to the last month was reported for the Ginchi area by Mihiretu (2020). The pH values were typically reduced as a result of drying and then continued to decrease over a period of two to twelve months. Long-term soil sample storage at pH has a significant difference at $p<0.05$.

As observed from the figure above the three storage materials has no significant effect on soil pH, on the other hand the storage time has a significant difference between time interval on soil pH analyses.

3.3. Effect of long term soil sample storage on soil total nitrogen content

The highest mean concentration of total nitrogen from vertisol and andosol was obtained in the 2nd month and the lowest mean concentration in the 12th month, as indicated in Figure 2 below. The total nitrogen concentration in soil samples stored for one year under laboratory conditions has decreased numerically from month two to month twelve. According to Zha et al. (2012), the effect of time and storage conditions on some soil chemical properties has been studied as most studies have focused on drying effects over short periods, from a few days to a few weeks, while the actual storage time may be several years. Birch (1958) also reported that the indication of changes occurs both during the drying process and on rewetting prior to analysis and the mineralization of nitrogen, possibly because of the breaking of hydrogen bonds within the organic matter of the soil and increased microbial activity. The current study shows that the total nitrogen in the soils of vertisol and andosol has not been stored for more than ten months for further analysis because the nitrogen is removable and the concentration of the total nitrogen would decrease significantly through the duration intervals. Results also indicated that the storage materials have no significant differences between the soil types; nevertheless, the mean concentration of total nitrogen decreased from time to time, as shown in Figure 2.

3.4. Effect of long term soil sample storage on soil available phosphorous

The highest mean concentration of available phosphorus (mg kg^{-1}) determined from vertisol and andosol soil samples stored for one year was obtained in the second month, and the lowest mean concentration of available phosphorus was found in the last month of the analysis, as shown on Figure 3. The availability of phosphorus in the stored soil samples decreased from months two to twelve in both soil types of the study soil samples. The effect of long-term storage soil sample on phosphorus availability varies significantly by month. Some authors suggest that when extractable Fe was decreased with higher temperature while available phosphorus increased, changes in other nutrient concentrations (K, Ca, Mg, Mn, Cu, Zn, Mo) were negligible (Soulides and Allison, 1961; Saarinen, 1989; Shuma, 1980). Payne and Rechcigl (1989) observed that

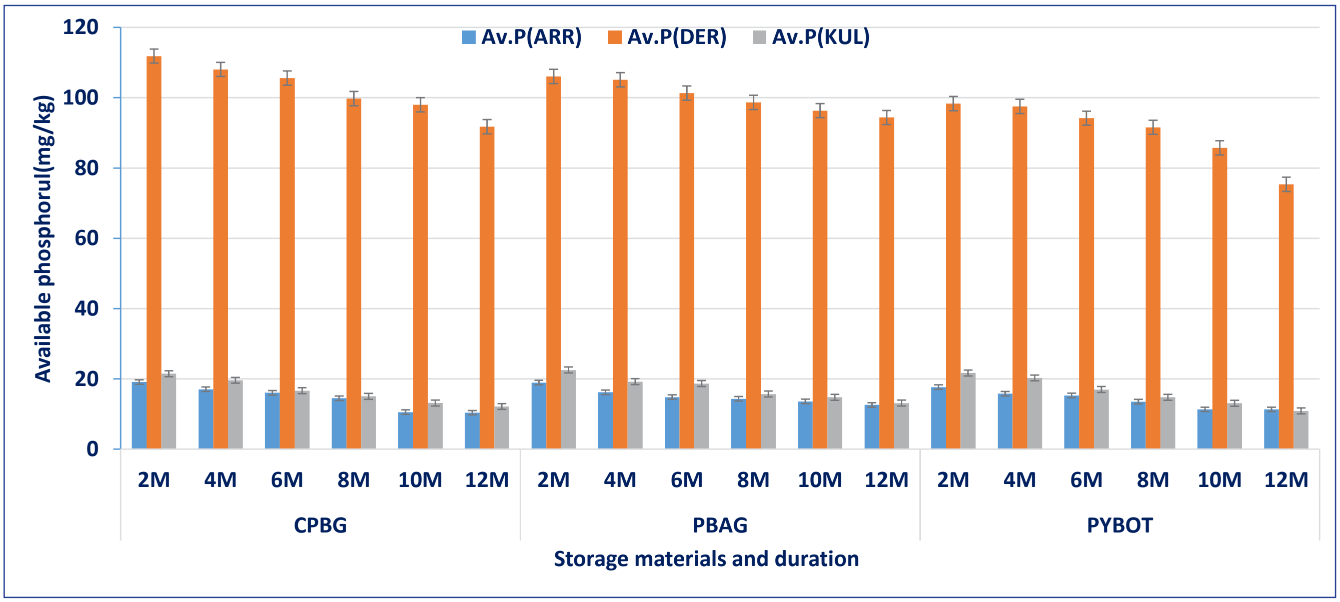

Figure 3: Effect of storage time on soil available phosphorus; Where, CPBG: Card box with plastic bag; PBAG: Plastic bag, PYBOT: Polytelene bottle; ARR: Arsi Robe; DER: Dera; KUL: Kulumsa; M: Months

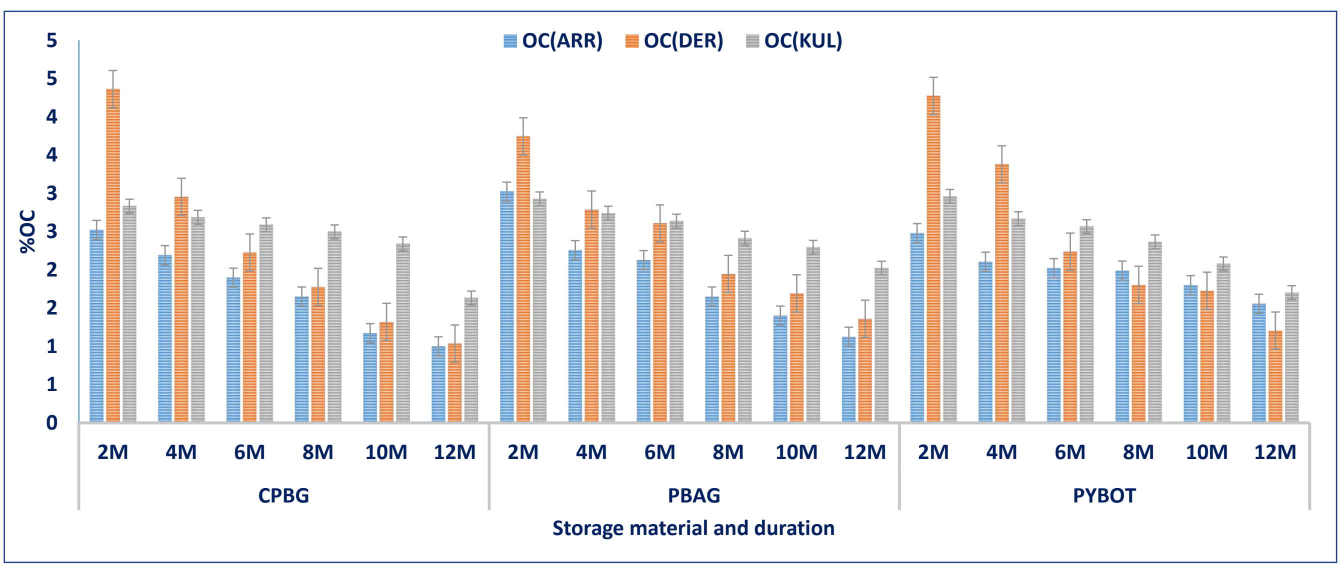

Figure 4: Effect of storage time on soil organic carbon; Where, CPBG: Card box with plastic bag; PBAG: Plastic bag, PYBOT: Polytelene bottle; ARR: Arsi Robe; DER: Dera; KUL: Kulumsa; M: Months

the extractable phosphorus has been changed considerably with temperature, also in the air-dried soil as compared to the moist soil. Based on the above assumption, the results of the available phosphorus analyzed for the year decreased from the initial soil analysis to the last analyses. The results also showed that there were no significant differences in storage materials between soil types; however, the mean concentration of available phosphorus decreased over time, as shown in figure 3.

3.5. Effect of long term soil sample storage on soil organic carbon content

The highest mean concentration of organic carbon content in Arsi Robe, Dera, and Kulumsa sites in the 2nd month (3.02, 4.36, and 2.96%) and the lowest mean concentration in the 12th month (1.00, 1.04, and 1.63%) were respectively shown in figure 4 below. Like available phosphorus and total nitrogen, the result of organic carbon analyzed for one year decreased simultaneously from the second month to the 12th month. According to Laura (1975), soil sample drying would result in the breakdown of organic matter, and air-drying of soil samples has been found to enhance the mineralization of organic matter as air-drying increases the solubilization of organic matter and disrupts soil aggregates. According to Bartlett and James (1980) the appropriate storage time, studied over 16 weeks, was a continuous change towards an increase in surface acidity, exchangeable Mn, solubility, and oxidizability of organic matter, which may decrease the organic contents in the soil. The current study shows that the soil from vertisol and andosol for organic carbon in soil has not been stored for more than ten months for further analysis because the organic carbon content of the soil has a relationship with the soil's total nitrogen and their concentrations would be significantly decreased through the duration intervals. Results also indicated that the storage materials had no significant differences between the soils types, nevertheless, the mean concentration of organic carbon decreased from time to time, as shown in Figure 4 below.

Sun et al. (2015) observed that air-drying of soil samples has been found to enhance the mineralization of organic matter as air-drying increases the solubilization of organic matter and disrupts soil aggregates. Soil samples may influence both the physicochemical and biological properties of soils in such cases. Air-drying has been reported to decrease soil pH and increase extractable Mn, Fe, Cu, and Zn contents and is considered to be the worst storage method if soil biological properties are to be studied on those stored samples, as it may cause the death of some bacteria because of hydric stress caused by the osmotic effects of the drying and rewetting process, which effects on soil results as suggested by (Soulides and Allison, 1961; Codling and Eton 2014). This study was agreed upon with the above scholars on organic carbon content decreases as sample storage is not avoidable in many cases for reasons of time limitation.

3.6. Effect of storage materials and method on soil sample

A common method to preserve soil samples for future analyses has been to store them air-dried in plastic bags in unheated storage room, and which has been probably encourage some fluctuations in soil moisture during storage and temperature may vary significantly (Lee et al., 2007).

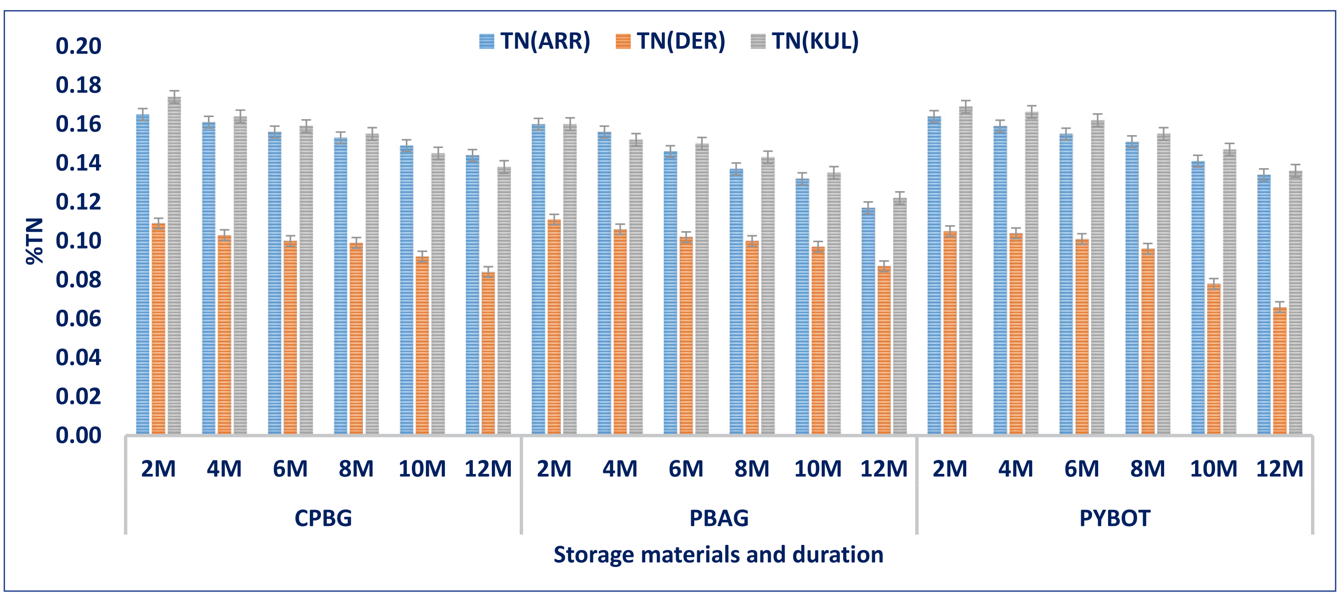

Figure 2: Effect storage time on soil total nitrogen content; Where, CPBG: Card box with plastic bag; PBAG: Plastic bag, PYBOT: Polytelene bottle; ARR: Arsi Robe; DER: Dera; KUL: Kulumsa; M: Months

The storage material used for soil sample storage during the study were plastic bag, polytelene bottle, and card box with plastic bag. As shown in Table 2. below, there was no significant difference between plastic bag and polytelene bottle for soil reaction (pH), but there was significant difference on card box with plastic bag when compared with other storage materials. The mean concentration of total nitrogen within the three storage materials were significantly different to each other. The available phosphorus has no significant difference between plastic bag and card box with plastic bag, but has been significant difference in case of polytelene bottle materials. In line with the current findings, Lee et al. (2015), observed a common method to preserve soil samples for future analyses has been to store them air-dried in plastic bags in unheated storage room due to its easily availability. The organic carbon content of the soil sample stored under the three materials was not significantly different to the storage materials as shown in Table 2 below.

Table 2: Effect of storage materials on soil sample stored for long term

Parameters	Materials		
	PBAG	PYBOT	CPBG
pH	6.183[b]	6.204[b]	6.264[a]
TN (%)	0.156[c]	0.160[b]	0.166[a]
Av.P	28.561[a]	27.253[b]	29.123[a]
OC (%)	2.675[a]	2.642[a]	2.639[a]

PBAG: Plastic bag; PYBOT: Polytelene bottle; CPBG: Card box with plastic bag

Although this study suggests that soil samples should be analyzed immediately after sampling and sample storage is not avoidable in many cases for reasons of time limitation. The occurrence of the significant difference between the materials may be due to the materials has absorbed the environmental moisture content during the soil sample analysis through the two months.

4. CONCLUSION

The long-term effects of soil sample storage on soil properties are not fully understood. The results showed that long-term soil sample storage has effects on soil chemical properties. Soil pH, TN (%), available phosphorus, and OC (%) have significantly decreased from the 2nd month to the 12th month. The long-term storage of soil had an effect on the soil's results, and the soil sample was analyzed up to the tenth month before the soil's chemical properties decomposed into other properties.

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