

Influence of the Storage Duration at Different Temperatures on the Concentrations of Extractable Inorganic Soil Nutrients

Jamal T. Elfaki¹, Ahmed M. Nour², Magboul M. Sulieman^{3*}, Mushtaha E. Ali⁴

¹Faculty of Agriculture, Nile Valley University, Atbara, Sudan

²Agricultural Research Corporation, Wad Medani, Sudan

³Department of Soil and Environment Sciences, University of Khartoum, Khartoum, Sudan

⁴General Administration of Natural Resource and Sustainable Development, Khartoum, Sudan

Email: *magboul@uofk.edu

Received 18 February 2016; accepted 2 May 2016; published 5 May 2016

Copyright © 2016 by authors and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

The influence of the short storage periods at different temperatures on the concentrations of extractable soil cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) and anions (Cl^- , SO_4^- and PO_4^-) has been investigated in nine soil samples from Nile river terraces at River Nile State, North of Sudan (17.82289 to 17.82389N and 33.99974 to 34.02127E). Each soil extract is divided into three treatments: i) control (immediately analyzed); ii) storage for 10 days and; iii) storage for 30 days. Each treatment is replicated three times: i) storage at 10°C; ii) storage at ambient laboratory temperature (25°C) and; iii) storage at 45°C in incubator. Statistical analysis of results reveals that significant difference are found at level ($P < 0.05$) for K^+ , Mg^{2+} , Ca^{2+} , Cl^- , SO_4^- and PO_4^- (0.043, 0.002, 0.001, 0.021, 0.004 and 0.001) respectively at 25°C and 45°C and storage periods of 10 and 30 days. In contrast, significant difference is also found at level ($P < 0.001$) for soluble calcium, magnesium and sulphate. In addition, results also reveal that SO_4^- concentrations are significantly decreased when the storage period exceeds 10 days and temperature more than 25°C. Depending upon our study results; we conclude that, all extractable inorganic nutrients are clearly affected by storage periods at various temperatures, exception of Na^+ . Most cations and anions are increased significantly with increased of storage period and temperatures. We therefore highly recommend that the extractable inorganic soil nutrients should be rapidly analyzed in order to obtain accurate results; otherwise, the time between extraction and analysis should be carefully recorded which may help considerably interpreting data from various studies.

*Corresponding author.

How to cite this paper: Elfaki, J.T., Nour, A.M., Sulieman, M.M. and Ali, M.E. (2016) Influence of the Storage Duration at Different Temperatures on the Concentrations of Extractable Inorganic Soil Nutrients. *Journal of Agricultural Chemistry and Environment*, 5, 66-72. <http://dx.doi.org/10.4236/jacen.2016.52007>

Keywords

River Nile State, Extractable Soil Cations, Storage Period, Inorganic Nutrients

1. Introduction

Soil chemistry changes through the time, as biological and chemical processes break down or combine compounds through the time. These processes change once the soil is removed from its natural ecosystem (flora and fauna that penetrate the sampled area) and environment (temperature, moisture, and solar light/radiation cycles). As a result, the chemical composition analysis accuracy can be improved if the soil is analyzed soon after its extraction [1].

The soil-fresh sample received in the laboratory should be analyzed directly after sampling for determination of nitrate, nitrite and ammonium. The chemical changes in the soil can be slowed during storage and transportation by freezing it. Air-drying can also preserve the soil sample for many months. Lag time between field sampling and analysis must be minimized. Otherwise, storage time will inevitably introduce an additional factor influencing analysis results [2].

Soil samples are often store before starting the physiochemical properties analysis. This can affect subsequent concentrations of extractable inorganic nutrients, including NH_4^+ and NO_3^- [3], K^+ [4] and SO_4^- [5]. Moreover, recent study reports that, at 10°C the values of soluble potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}) are increased to 10% [6].

Sample handling and storage are more important aspects of soil analysis than generally recognized. [7] presents data indicating problems associated with drying and storing soil samples and changes that occur under various sample and storage conditions.

In this study, we assessed the influence of short storage periods at different temperatures on the concentrations of extractable soil cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) and anions (Cl^- , SO_4^- and PO_4^-) in soils of the Nile river terraces at River Nile State, North of Sudan. We tested the hypotheses that i) extractable inorganic nutrients concentrations would be significantly change during different storage periods as well as different temperatures; ii) extractable inorganic nutrients concentrations would be positively correlated with soil formed at different time but derived from similar parent materials; iii) chloride (Cl^-) and sulphate (SO_4^-) concentrations would be most changed during storage periods at different temperatures.

2. Materials and Methods

2.1. Site Description

The study area is located in North of Atbara city, River Nile State, Sudan, with an altitude of (336 - 358 meters) above sea level. The study area covered about 8000 ha and is located where the coordinate is at 17.82289 to 17.82389N and 33.99974 to 34.02127E. According to [8], the study area falls within the arid climatic zone. The average annual rainfall varies from 0 to < 100 mm. Mean maximum temperature of the hottest months (May and June) is 43°C . Mean minimum temperature of the coldest month (January) is less than 13°C . The mean annual relative humidity ranges between 15% to 21% (January to February), less than 15% (March to June). The predominant natural vegetation in the study area consists of the following species: Tundub (*Capparis decidua*), Seyal (*Acacia tortilis*), Usher, Musket (*Prosopis chilensis*), Heglig (*Balanites aegyptiaca*) and Seder (*Zizyphus spina-christi*). The calculated soil temperature regime is hyperthermic and soil moisture regime is aridic. According [9], the soils of the study area belong within Entisols and Aridisols orders.

2.2. Soil Sampling and Preparation

Nine soil samples were collected from different Nile river terraces at River Nile State, North of Sudan (Table 1). At each site, approximately 5 kg of soil sample was collected from the depth of 0 - 30 cm using an auger and kept in a plastic bag. In the laboratory, soil samples were air-dried and passed through a 2 mm mesh sieve to obtain the fine earth fraction. To estimate the influence of storage period at different temperatures on the concentrations of soluble cations and anions, a 1:5 soil suspension was shaken for 30 minutes, and then extracted

Table 1. Description of samples sites in the study area and some physical and chemical properties.

Site No.	Description	Location		Elevation (m-a.s.l)	Partial Size Distribution%			Texture Class	CaCO ₃ (%)
		N	E		Sand	Silt	Clay		
1	First Terrace	17.81779	33.99229	349	48.38	47.77	3.85	Sandy Loam	5.50
2	Second Terrace (Farm of Agric. College)	17.82389	33.99974	353	86.12	12.13	1.75	Sand	2.58
3	Second Terrace (Instructional Farm)	17.82289	34.02127	358	32.61	61.14	6.25	Silt Loam	7.40

with filter paper (Whatman No. 42). Each soil extract then divided into three treatments: i) control (time zero) or immediately analyzed); ii) storage for 10 days and; iii) storage for 30 days. Each treatment was replicated three times: i) storage at 10°C; ii) storage at ambient laboratory temperature (25°C) and; iii) storage at 45°C in incubator.

2.3. Estimation of Soil Properties

The particle size distribution of the subsamples was determined using Particle size analyzer model (Mastersizer 2000, Malvern) and the soil texture class was determined using USDA Textural triangle [10]. Soil pH was measured in 1:5 soil suspensions using a digital pH meter Model (3510, Jenway) and the results were compared according to the classification of [11]. The electrical conductivity (EC dS/m at 25°C) was determined in 1:5 soil extract using a conductivity meter Model (4510, Jenway) [12] and the results were compared according to the classification of [13]. Percent calcium carbonate (%CaCO₃) was estimated by Calcimeter. The samples were treated with 0.1N HCL; the volume of CO₂ from pure calcium carbonate and samples were recorded. The percent calcium carbonate was then calculated according to [14]. Extractable cations (Ca²⁺, Mg²⁺, Na⁺ and K⁺) and anions (Cl⁻, SO₄⁻ and PO₄⁻) were determined in 1:5 soil extraction.

2.4. Statistical Analysis

Changes during storage period at 10 and 30 days were determined by repeated measures analysis of variance using storage period and treatment (10°C, 25°C and 40°C) as factors. Values for fresh extracts (control) were compared with those from extracts stored for 10 and 30 days by one-way analysis of variance with Turkey's significant difference test for mean separation ($P < 0.05$). All statistical analysis was performed using SPSS software version 16.0 (SPSS Inc, USA).

3. Results and Discussion

3.1. Selected Chemical and Physical Properties

The description of the samples sites in the study area and some of the physical and chemical properties are presented in **Table 1** and **Table 2** respectively. The soil texture ranged from sandy loam in the first terrace, silt loam in the second terrace (Instructional farm). While the soil texture in the Agricultural College farm was sand. This could be due to the fact that these soils falls in the mining area which are truncated soils. The soils of the study area were moderately calcareous and the %CaCO₃ ranged from 2.58% to 7.40%. The soil reaction (Soil pH) varied from alkaline to strongly alkaline with a pH value ranged from 7.46 to 8.80 [11]. According to [13], the soils of the study area were non-saline and the electrical conductivity (EC_e) ranged from 0.22 to 0.57 dS/m. The predominant soluble cations and anions in the study area were (Na⁺ and Ca⁺⁺), (HCO₃⁻ and Cl⁻) respectively.

3.2. Influence of the Storage Period on the Concentrations of Extractable Nutrients

Comparing first and second storage period there were significant difference at $P < 0.05$ found in all estimated cations (**Table 3** and **Figure 1**) respectively, except for Na⁺ and K⁺. The Ca²⁺ and Mg²⁺ concentrations were significantly increased from 11.22 ± 1.978^a to 17.503 ± 4.047^b and from 3.790 ± 2.794^a - 5.568 ± 3.722^b respectively. Similar trend were found when comparing 10 days with 30 days storage period, Ca²⁺ and Mg²⁺ concentrations were significantly increased from 17.503 ± 4.047^b to 23.505 ± 5.998^c in addition to K⁺ concentration

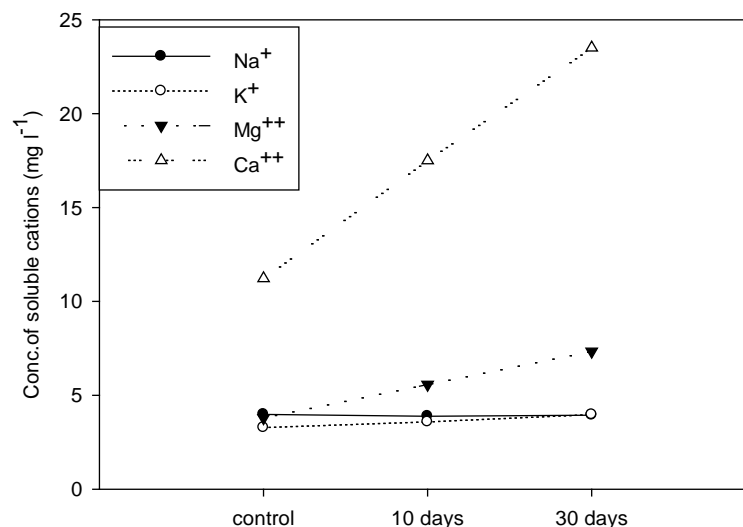


Figure 1. Change in soluble soil cations concentrations at different storage periods.

Table 2. Selected soil chemical properties of soils of the study area.

Site No.	pH (1:5)	EC (dS/m)	Cations (meq/L)				Anions (meq/L)				
			Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	PO ₄ ⁻	Cl ⁻	NO ₃ ⁻	SO ₄ ⁻	HCO ₃ ⁻
1	8.73	0.219	1.699	0.547	0.196	0.558	0.050	0.538	0.090	0.290	2.193
2	8.46	0.250	1.106	0.281	0.503	0.640	0.063	0.575	0.460	0.186	1.377
3	8.80	0.570	2.811	0.248	0.172	0.352	0.057	0.522	0.081	0.643	2.424

Table 3. Influence of storage period on the concentrations of soluble soil cations.

Cations	Treatments (storage period)		
	Time zero	10 days	30 days
Na ⁺	3.984 ± 5.675 ^a	3.881 ± 5.6636 ^a	3.943 ± 5.733 ^a
K ⁺	3.279 ± 1.243 ^a	3.582 ± 1.306 ^a	3.968 ± 1.430 ^b
Mg ²⁺	3.790 ± 2.794 ^a	5.568 ± 3.722 ^b	7.334 ± 4.739 ^c
Ca ²⁺	11.22 ± 1.978 ^a	17.503 ± 4.047 ^b	23.505 ± 5.998 ^c

Means in each row with different letters are significantly different at $P < 0.05$.

which increased from 3.582 ± 1.306^a to 3.968 ± 1.430^b . These obtained results were expected specially increasing the storage period logically content in soluble solution. When we compared first and third storage period there were significant difference found in K⁺ and highly significant difference observed in Mg²⁺ (from 3.790 ± 2.794^a to 7.334 ± 4.739^c) and Ca²⁺ (from 11.22 ± 1.978^a to 23.505 ± 5.998^c) at $P < 0.05$ level. [15] reported that extractable Ca²⁺, K⁺, and Mg²⁺ were less influenced by storage period, although the effects varied among soil types.

In anions part (Table 4 and Figure 2) respectively, while comparing first and second period results shown that Cl⁻ and PO₄⁻ concentrations were significantly increased from 0.318 ± 3.553^a to 0.749 ± 1.498^b and 0.808 ± 3.550^a to 0.885 ± 5.710^b respectively. However, SO₄⁻ concentrations were highly significant decreased (from 12.67 ± 2.158^a to 3.577 ± 3.186^c) with increased of storage period. Similar results were obtained by [15]. Contrasting, [16] reported that soil storage before separation of the soil solution by centrifugation caused a marked decline in P concentrations.

3.3. Influence of Temperatures on the Concentrations of Extractable Nutrients

Comparing first and second temperature (10°C and 25°C), significant different were found in Mg²⁺ and Ca²⁺

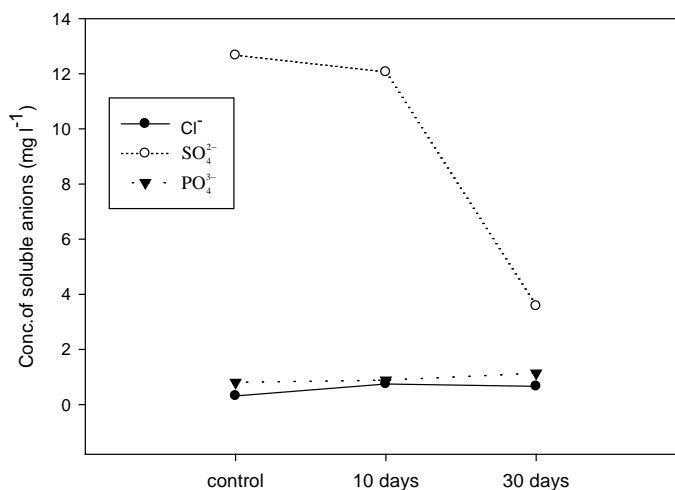


Figure 2. Change in soluble soil anions concentrations at different storage periods.

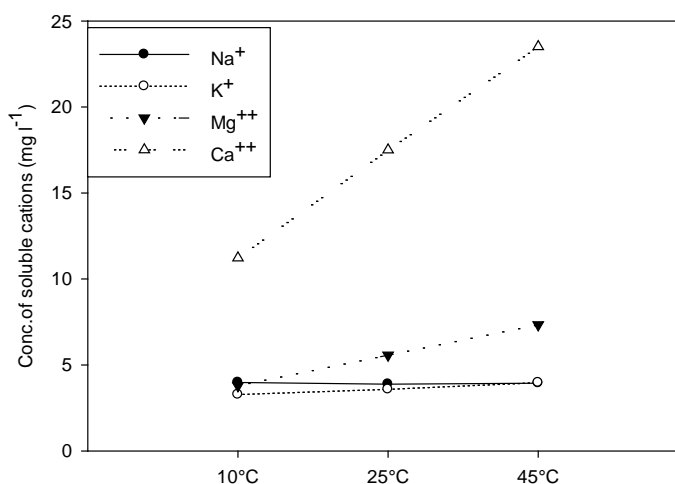


Figure 3. Change in soluble anions concentrations at different temperatures.

Table 4. Influence of storage period on the concentrations of soluble soil anions.

Anions	Treatments (storage period)		
	Time zero	10 days	30 days
Cl ⁻	0.318 ± 3.553 ^a	0.749 ± 1.498 ^b	0.664 ± 1.631 ^b
SO ₄ ²⁻	12.67 ± 2.158 ^a	12.063 ± 2.120 ^a	3.577 ± 3.186 ^c
PO ₄ ³⁻	0.808 ± 3.550 ^a	0.885 ± 5.710 ^b	1.143 ± 5.586 ^b

*Means in each row with different letters are significantly different at $P < 0.05$.

from 3.790 ± 1.452^a to 5.568 ± 1.934^b and 11.22 ± 1.028^a to 17.503 ± 2.103^b respectively. Similarly significant different are found while comparing K⁺ in second and third temperature (25°C and 45°C), and highly significant different were found while comparing second and third temperature in Mg²⁺ and Ca²⁺ respectively (Table 5 and Figure 3). Similar results were obtained by [15]. Additionally, change in K⁺ and Ca²⁺ concentrations during low temperature storage were observed to be less significant and associated with soil types [17].

Comparing first and second temperature (10°C and 25°C), significant different were found in Cl⁻ and PO₄³⁻ from 0.318 ± 0.185^a to 0.749 ± 0.779^b and 0.808 ± 1.844^a to 0.885 ± 2.967^b respectively. [14], in their study reported that, extractable PO₄ of Refrigerated samples always contained lower values than counterparts stored at

room temperature. They also pointed out that, extractable PO_4^- were significantly differences among the soil types. Moreover, the amounts of extractable PO_4^- were significantly increased during low temperature storage [15]. In contrast, [17], reported that soil storage before separation of the soil solution by centrifugation caused a marked decline in P concentrations, including those of molybdate-reactive P and dissolved organic P, within a few days. However, SO_4^- concentrations were significantly influenced by increased temperature (Table 6 and Figure 4).

4. Conclusion

Depending on our results, all investigated cations and anions were clearly affected by storage periods at various temperatures, exception of Na^+ . Most cations and anions were increased significantly with increased of storage period and temperatures, while some anions (such as SO_4^- and Cl^-) were dramatically decreased with increased of storage period and temperatures. Despite the simplicity of this research and some limitations such as design which was performed, but the obtained results confirmed that the storage periods and temperatures were influenced markedly on the concentrations of different extractable inorganic soil nutrients. We therefore highly

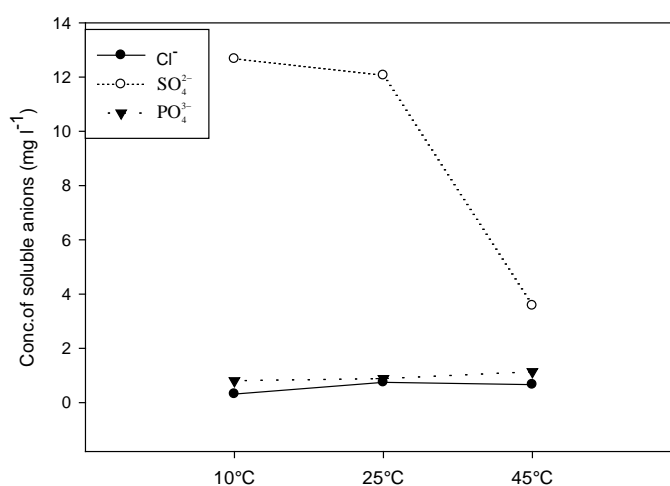


Figure 4. Change in soluble anions concentrations at different temperatures.

Table 5. Influence of storage period on the concentrations of soluble soil anions.

Cations	Treatments (storage period)		
	10°C	25°C	45°C
Na^+	3.984 ± 29.49 ^a	3.881 ± 29.426 ^a	3.943 ± 29.794 ^a
K^+	3.279 ± 0.645 ^a	3.582 ± 0.679 ^a	3.968 ± 0.743 ^b
Mg^{++}	3.790 ± 1.452 ^a	5.568 ± 1.934 ^b	7.334 ± 2.463 ^c
Ca^{++}	11.22 ± 1.028 ^a	17.503 ± 2.103 ^b	23.505 ± 3.117 ^c

*Means in each row with different letters are significantly different at $P < 0.05$.

Table 6. Influence of temperature on different concentrations of soluble anions.

Anions	Treatments (temperature)		
	10°C	25°C	45°C
Cl^-	0.318 ± 0.185 ^a	0.749 ± 0.779 ^b	0.664 ± 0.848 ^b
SO_4^-	12.67 ± 11.21 ^a	12.063 ± 11.02 ^a	3.577 ± 1.314 ^c
PO_4^-	0.808 ± 1.844 ^a	0.885 ± 2.967 ^b	1.143 ± 2.902 ^b

*Means in each row with different letters are significantly different at $P < 0.05$.

recommended that the extracted inorganic soil nutrients should be rapidly analyzed in order to obtain the accurate results.

Acknowledgements

The authors are greatly indebted to dean of Agriculture College and general manager of Educational Farm, Nile Valley University.

References

- [1] Boczulak, S.A., Hawkins, B.J. and Roy, R. (2014) Temperature Effects on Nitrogen Form Uptake by Seedling Roots of Three Contrasting Conifers. *Tree Physiology*, **5**, 513-523.
- [2] International Center for Agricultural Research in the Dry Areas (2013) Methods of Soil, Plant, and Water Analysis: A Manual for the West Asia and North Africa Region George.
- [3] Mulvaney, R.L. (1996) Nitrogen—Inorganic Forms. In: Sparks, D.L., *et al.*, Eds., *Methods of soil analysis. Part 2. Chemical Properties*, Soil Science Society of America, Madison, Wisconsin, USA, 1123-1184.
- [4] Luo, J.X. and Jackson, M.L. (1985) Potassium Release on Drying of Soil Samples from a Variety of Weathering Regimes and Clay Mineralogy in China. *Geoderma*, **35**, 197-208.
- [5] Comfort, S.D., Dick, R.P. and Baham, J. (1991) Air-Drying and Pretreatment Effects on Sulfate Sorption. *Soil Science Society of America Journal*, **55**, 968-973.
- [6] Masashi, *et al.* (1999) Development of a New Multinutrient Extraction Method for Macro- and Micro-Nutrients in Arable Land Soil. *Soil Science & Plant Nutrition*, **46**, 299-313.
- [7] Richmond, B. and James, B. (1980) Studying Dried, Stored Soil Samples—Some Pitfalls. *Soil Science Society of America Journal*, **44**, 721-724. <http://dx.doi.org/10.2136/sssaj1980.03615995004400040011x>
- [8] Van der Kevie, W. (1973) Climate Zones in the Sudan. Soil Survey Department, Wad Medani.
- [9] Soil Survey Staff (2014) Keys to Soil Taxonomy. 12th Edition, United States Department of Agriculture, Natural Resources Conservation Service, Lincoln, 97, 123, 287.
- [10] Soil Survey Staff (2014) Kellogg Soil Survey Laboratory Methods Manual. In: Burt, R. and Soil Survey Staff, Eds., Soil Survey Investigations Report No. 42, Version 5.0, US Department of Agric. Natural Resources Conservation Service, Lincoln.
- [11] Marx, E.S., Hart, J. and Stevens, R.G. (1999) Soil Test Interpretation Guide. Oregon State University, 1-8.
- [12] U.S. Salinity Lab. Staff (1954) Diagnosis and Improvement of Saline and Alkali Soils. Agricultural Handbook No. 60, United State Department of Agriculture.
- [13] Rhoades, J.D. (1996) Salinity: Electrical Conductivity and Total Dissolved Solids. In: Sparks, R.L., Ed., *Methods for Soil Analysis, Part 3: Chemical Methods*, Soil Science Society of America, Madison, 417-435.
- [14] Horváth, B., Opara-Nadi, O. and Beese, F. (2005) A Simple Method for Measuring the Carbonate Content of Soils. *Soil Science Society of America Journal*, **69**, 1066-1068.
- [15] Turner, B.L. and Romero, T.E. (2009) Short-Term Changes in Extractable Inorganic Nutrients during Transport and Storage of Tropical Rain Forest Soils. *Soil Science Society of America Journal*, **73**, 972-1979.
- [16] Chapman, P.J., Shand, C.A., Edwards, A.C. and Smith, S. (1997) Effect of Storage and Sieving on the Phosphorus Composition of Soil Solution. *Soil Science Society of America Journal*, **61**, 315-321.
- [17] Allen, S.E. and Grimshaw, H.M. (2006) Effect of Low Temperature Storage on the Extractable Ions in Soils. *Journal of the Science of Food and Agriculture*, **13**, 525-529.