American-Eurasian Journal of Scientific Research 15 (4): 161-169, 2020
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2020.161.169

Evaluation of Common Extractants for the Extraction of Selected Macronutrients from Soil of East Hararghe and Bako, Ethiopia

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Abstract: The objective of this study was to compare the effectiveness of selected universal soil extractants (M 3, 0.02M $SrCl_2$ and Kelowna) in their extraction efficiency for the determination of P, NO_3^- and K compared to the traditional procedures. The study was conducted using completely randomized design method in three replications at Haramaya University Laboratory by collecting eight soil samples from Haramaya, Dire Dawa, Babile and Bako. From the results obtained, Mehlich 3 extraction methods were found to be the most suitable for the determination of P in neutral and basic soils and Kelowna extraction method was found to be the most suitable in acidic soils. However, very close relationship was found between these extractants and conventional soil testing methods. The amount of nitrate determined by Kelowna and 0.02M $SrCl_2$ were higher than the Mehlich 3 extractant used in this study and these extractants were found to be the most suitable extractants for the determination of nitrate in basic soils and also well close relationship were found between these extractants and conventional soil testing method with ($p < 0.05$ and $r = 0.73$) and ($p< 0.05$ and $r = 0.70$) respectively. On the other hand the amount of nitrate determined by Kelowna was found to be the most suitableextractant than others for basic, acidic and neutral soils and also very close relationship was found between this extractant and conventional soil testing method with ($p<0.05$ and $r = 0.73$). The amount of K determined by 0.02M $SrCl_2$, Mehlich 3 and Kelowna were higher in acidic soil. On the other hand 0.02M $SrCl_2$ was found to extract large amounts of K than others. Generally the amounts of exchangeable K determined by ammonium acetate (NH_4OAc) method was significantly correlated to the amounts determined by universal extractants tested with ($p<0.001$, $r= 0.999$). In general, both 0.02M $SrCl_2$ and Kelowna can serve as universal extractants for the macronutrients considered in this study.

Key words: K, NO_3^-, P, Soils · Universal Extractants

INTRODUCTION

The term universal soil extractant has been used to name reagents or procedure to evaluate several elements and ions from a soil to find out fertility status and/or metal toxicity [1]

The first purpose of each extractant is the determination of available nutrients for plants. Two parameters are very important, when an extractant is utilized: (i) evaluating the nutrient labile form and (ii) extracting methods that are fast and economic [4]. Soil testing is measurement of the physical and chemical properties of soils. The result of soil chemical testing is instrumental in determining the relative ability of a particular soil to supply plant nutrients during a particular crop growing season, to predict the probability of obtaining a profitable response to fertilizer application, to determine the need to adjust soil pH, diagnose problems such as excessive salinity or sodicity/alkalinity, provide a basis for fertilizer recommendations for a given crop and to evaluate the fertility status of soil as the basis for planning a nutrient management program. The main problem in the use of single soil testing or extraction method lies in the lack of uniformity in the different procedures used. As consequence, the results obtained are operationally designed depending on the experimental conditions used (type and concentration of extracting agent, soil mass to volume ratio, shaking time and speed

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of shaking [30]. Soils are highly variable and complex and developing single extraction method specific to the soil of interest makes the job expensive and time consuming. Therefore, developing a universal extractant that does an acceptable job of accuracy in identifying plant available nutrient is required [10].

Regardless of their present drawbacks chemical methods of agricultural soil testing are the most frequently used tools of diagnostics of the nutrient status of soil and the need of fertilization derived from it. The main advantage of soil tests is a possibility of preventing potential disorders of the nutrient status of the crop before its own cultivation in a given field. Soil testing is as a remarkable and unique activity that synthesizes a large amount of research information and scientific knowledge for practical needs of the identification and prevention of the majority of disproportions in plant nutrition [31]. Soil testing provides farmers with the highest quantity of practically applicable information. Today's challenge is to select from the collection of soil extraction tests such methods that allow simultaneous extraction of several nutrients so that it will be possible to make full use of the advantages of multi-element analyzers, e.g. ICP[15, 29]. A crucial condition is that the soil test will identify a similar source of nutrients that will really be available to plants [29, 31]. The majority of the present methods of soil tests date back to the period after World War I, i.e. to the beginnings of more intensive use of commercial fertilizers when the sensitivity of analytical methods was lower. This drawback is compensated by a higher strength of nutrient extraction from the soil that has been handed down until now e.g. in Mehlich-3 extraction used in developed country. After the intensity of application of commercial fertilizers of NPK type has increased, it was necessary to have more detailed information on the storage rate and complex of all nutrients including trace elements in the soil. There is also an increasing need for more exact determination of nutrient availability to plants in a wide range from deficiency through optimum to excess and their mutual relations and interactions. Such a specification is essential for the needs of fully effective management of nutrient inputs (economic aspect) and indispensable load of soil (ecological aspect). The improvement and precision of diagnostic methods of the nutrient status of soils is an instrument significantly contributing to the improvement of technologies of better utilization of plant nutrients for the formation of yields of agricultural crops with high-quality parameters and without harmful impacts on the environment at the same time.

Requirements for a modern method of soil test can be summarized in the following seven items [1, 36]: (1) Simultaneous extraction of all important nutrients from the soil (so called multinutrient test). (2) Functionality in all kinds and types of soils, i.e. existence of the best possible compliance of extracted nutrients from heterogeneous soils with their real bioavailability – requirement of universality. (3) Accuracy– reproducibility. (4) Simplicity. (5) Reasonable price in agreement with the utility value of information. (6) Expeditious (fast) detection. (7) Reflection of mechanisms (parameters) influencing the availability of a nutrient to plants from the soil in a given site – field. Of course, none of the present methods of soil testing fulfils these ideal parameters. But the suitability of methods can be evaluated by considering how they approximate the above mentioned criteria. Authors such as [1, 36] believe that soil tests may be improved by the use of ion-exchange resins that can simulate the mechanism of nutrient transport to roots – to the sink. But the methods using ion-exchange resins are more labour and time consuming.

Unbuffered universal extractantsas reported by [21] may not be as effective as the conventional when single nutrient extraction is considered. Among the universal extractantsused for determination of NO_3^-, the 0.01M $CaCl_2$ could easily replace 0.5 M K_2SO_4 in some selected Ethiopian soils; but, in the other way 0.01M $CaCl_2$ is not suitable for other macronutrients in case of [20]. Theamount of available P estimated by 0.02 M $SrCl_2$ is greater for acidic soils, whereas the amount of available P estimated by Mehlich 3 is greater forneutral and alkaline soils in case of [20]. Here, 0.02M $SrCl_2$ universal extractant was not compared with convectional (Bray1) to determine available phosphorous from acidic soil. Therefore, this study was designed to get suitable universal extractantto replace the convectional soil testing methods. This study also focuses on multi-element soil testing methods to improve the above problem from Ethiopian soil by investigating three universal extraction methods and comparing them with convectional extraction methods to determine bioavailability of the selected nutrients (P, NO_3^-(N) and K).

MATERIALS AND METHODS

Study Areas: The study was conducted in some selected parts of Eastern Ethiopia, Viz., Eastern Hararghe (Haramaya Districts, Babile and Dire Dawa Administrative Council (DDAC)) and Western Ethiopia, Viz., West Shewa (Bako District) as shown in Figure 1.

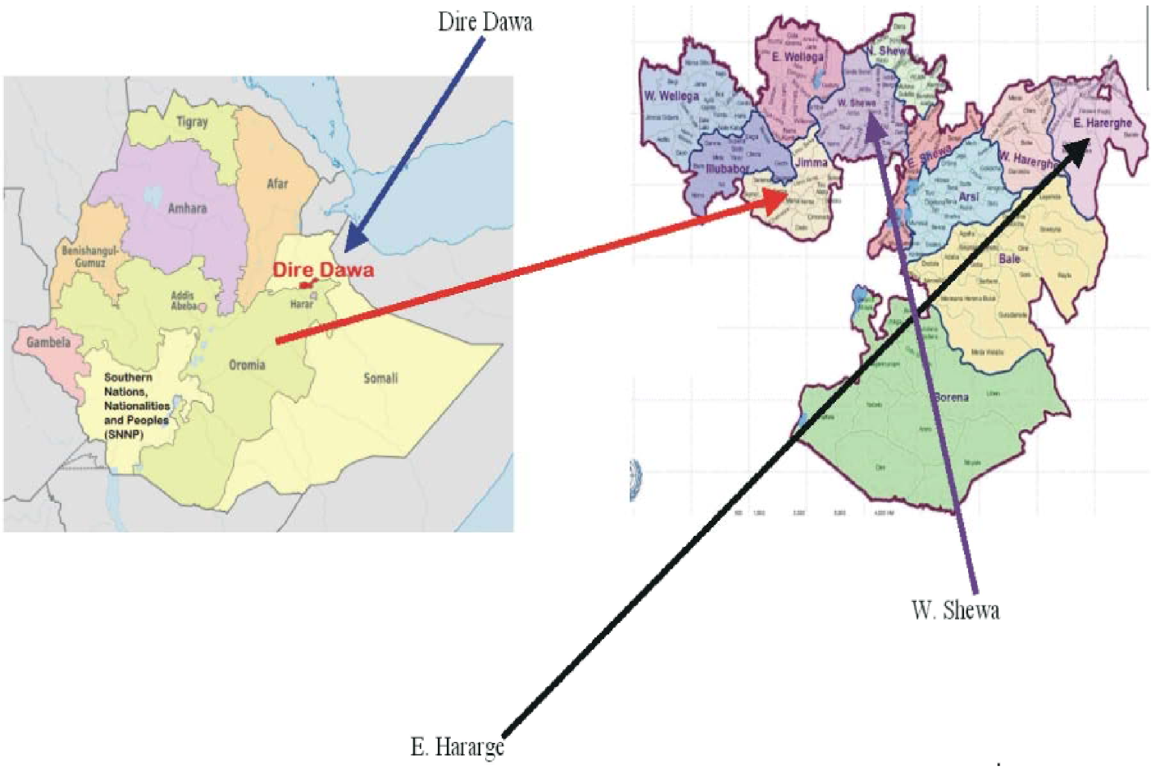

Fig. 1: Location of the study areas

Haramaya District is located on the Eastern escarpment of the Rift Valley near 09°26’ N and 41°55’ to 42°03’ E, at an altitude of 1970 to 1980 masl. Some of the dominant crops in this District are sorghum, maize, wheat and common beans. The total annual average rainfall is 827 mm and the mean temperature is 16.8 °C. BabileDistrict lies between 8°09' and 9°23' N latitude and between 42°15' and 42°53' E longitude and an altitude between 1239 and 1441 meters above sea level (masl). The rainy season of the area is bimodal. The annual rainfall varies from 450 to 900 mm and the annual mean maximum and minimum temperatures are 30.9 and 13.5°C, respectively. The Dire Dawa Administrative Council (DDAC) is geographically located in the eastern part of the country specifically at latitude and longitude of 9° 36' N and 41° 52' E, respectively. The DDAC comprises diversified topographic features. Its altitude ranges from 960 in the northeast to 2450 masl in the southwest. The cereal crops grown in the DDAC are sorghum and maize only. Besides the cereal crops, a variety of vegetables such as onion, tomato, pepper and cabbages, cash crops such as khat, coffee and fruit like papaya, banana and guava are also grown (Dire Dawa Administration, 2011). Bako is located on the Western Ethiopia with a latitude 09° 07’ N and longitude 37° 03’E. Thisdistrict represents one of the highest maize growing areas of the country positioned in mid-altitude humid ecology. The soil type is dominated by red loamy soil. The dominant crops grown in the district include maize, sorghum and teff. The area receives an average rainfall of 1101 mm per annum and the elevation ranges from 1568 m to 2604 m above sea level.

Study Area Selection: The sites were selected by purposive sampling in order to get soils having different pH values. The selected sites were the Eastern Harargie Zone (Babile and Haramaya District) for neutral and moderately alkaline soil, Bako Districts for acidic soil and Dire Dawa Administrative Council for alkaline soils.

Experimental Site: The study was conducted in three treatments (Mehlich3, 0.02 M $SrCl_2$and Kelowna) in the following laboratory rooms such as Central Laboratory, Instrumental Laboratory and soil Laboratory at Haramaya University.

Soil Sample Collection and Preparation: Composite surfaces oil samples (0-30 cm depth) were collected randomlyinzigzag pattern from eight sampling spots of

Table 1: Details of extraction procedure was used in the study for universal extractants soil testing method.

Methods used	Extractants	Soil: solution	Shaking time (min)	References
Mehlich 3	0.015 M NH_4F + 0.25 M NH_4NO_3 + 0.2 M CH_3COOH + 0.013 M HNO_3+ 0.001 M EDTA(pH=2.5)	1:10	5	[19]
Kelowna	0.25M CH_3COOH+ 0.015M NH_4F	1:10	5	[40]
Strontium chloride	0.02 M $SrCl_2$	1:10	30	[17]
Olsen	0.5 M $NaHCO_3$ (pH= 8.5)	1:20	30	[25]
Bray I	0.025M HCl + 0.03M NH_4F	1:5	1	[2]
Ammonium acetate	1 M NH4OAc (pH = 7)	1:20	30	[37]
Potassium chloride	2M KCl			[13]

the study are as before determination of some selected physico chemical properties of the soil. The soil samples were bagged, labeled and transported to the laboratory for preparation and analysis of selected soil properties following standard laboratory procedure.

Instrumentation: A stainless steel soil sampling auger was used to collect all the soil samples from sampling sites. All the soil samples were weighed on a digital analytical balance (Mettler Toledo, Switzerland) with ± 0.0001 g precision. A pH meter (model RS232) was used during pH measurement of the soil. The concentration of K in the soil samples was determined by a flame photometer (Jenway Ltd., England). The amounts of available P and nitrate (NO_3^-) in the soil samples were determined by UV-Visible Spectrophotometer (PG Instrument Limited, T80+, Vietnam).

Experimental Parameters: Thes oil samples were collected are allow sairing dry at room temperature and grinding to pass througha 2 mm sieve. Soil pH (H_2O) was determinedin 1:2.5 soil water suspension using glass electrodep Hmeter (Van Reeuwijk, 1992). SoilpH(KCl) was determined by dispersing 10gram of soilin 25mL of 1MKClafter 2 hrs haking at 20rpm with Orbitalshaker (model SO1) [4]. The texture of the soil was determined by the hydrometer method afterdispersion of the soil with sodium hexametaphosphate [5]. The calcium carbonatecontent of the soil was determined by acidneutralizationmethodby treating the soil sample with standard Hcl [14]. Organiccarbon of the soil was determinedby using Walkley and Black method by dichromate oxidation technique [23]. Cation exchange capacity (CEC) of the soil was determined from ammonium acetatesaturateds amples through distillation and measuring the ammonium using the modified Kjeldahl procedure as described by [3].

Soil Analyses: For conventional soil testing method, available phosphorus for alkaline soils were determined using the methods described by [25] and from acidic to neutral soils available phosphorus was determined by using Bray and Kurtz (Bray 1) [2]. Potassium in the soil sample was determined by using 1M ammonium acetate method and nitrate nitrogen was determined by using 2M Kcl. For the universal extractants, all the samples were analyzed using Mehlich-3, 0.02 M $SrCl_2$and Kelowna extractant and filtrated using whatman filter paper (540, 90 mm diameter).

Phosphorus in soil solution was calorimetrically determined by using Riley and Murphy method using ascorbic acid as reductant with UV- Visible spectrophotometer at 882 nm wavelengths [22]. Soil nitrate was determined calorimetrically by using phenoldisulfonic acid and the analysis was carried out using UV-Visible spectrophotometer at 415 nm [13]. Potassium (K) in soil solution was determined using flame photometer as described in [14]. Analysis of the same soil with the same extractant was triplicates. During the experiment when the solution appeared turbid or when there was precipitation on the bottom of the flask, the solution was left standing to let the suspended particles settle (5 minute) and the clean solution was used for analysis, [17].

Statistical Data Analysis: Analysis of variance (ANOVA) was used to test differences between two or more means. The general linear model (GLM) procedure of Statistical Analysis System version 9.1 [32] was used as a tool for statistical analysis and to test significance differences between treatments means. The least significance difference (LSD) test was employed for the mean separation of different methods that are found to be significantly different in statistical terms at P = 0.05.

RESULTS AND DISCUSSION

Soil analysis of the study areas showed that the soil samples were in the pH range between 5.59 and 8.34 (Table 2). The soil sample collected from Bako is moderately acidic. The greater acidity of the soil of Bako (Bk) District, might be due to the continuous application of nitrogen (N)–containing fertilizers for several years. Increasing rates of nitrogenous fertilizers generally increase soil acidity [28]. Nitrogenous fertilizers are known to produce hydrogen (H^+) ion by the following reaction, which is induced by soil bacteria [12]:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$$

Thus, during the application of these fertilizers to the soil, the rate of nitrification is reported to be greater and inorganic N may be rapidly converted to nitrate producing H^+, which acidifies the soil. The soil sample collected from Haramaya (HU) was found to be neutral or nearly neutral, the soil from Babile (Bb) was slightly alkaline and the soil from Dire Dawa (DD) was moderately alkaline.

The calcium carbonate content of the soil was high in Dire Dawa which was 4.8% and acidic toneutral soils under studied area showed no detectable amount of calcium carbonate (Table 2).

Thecation exchange values of the studied soil samples ranged from 13 (Babile) to 21 cmol/kg (Haramaya). The cation exchange capacity of the soil is strongly affected by the amount and type of clay and the amount of organic matter present in the soil. Soils with large amounts of clay and organic matter have higher cation exchange capacity than sandy soils which have low organic matter [21].

The organic soil matter includes all the dead plant materials and live or dead animals. Most living things in soils including plants, insects, bacteria and fungi are dependent on organic matter for nutrients and energy. Soils have varying organic compounds in varying degrees of decomposition. Organic matter holds soils open, allowing the infiltration of air and water and may hold as much as twice its weight in water [42]. In the present study, the organic carbon content of the soil samples were ranged from 0.04% in Babile to 1.9% Haramaya (Table 2). The low organic carbon in Babile soil is probably due to high amount of sand in the soil.

Table 2: Characteristics of the soil samples from the various study areas (mean ± S.D)

Site	pH (H_2O)	pH (KCl)	$CaCO_3$ %	CEC	Organic C %
Bk	5.59±0.58	4.65±0.03	-	19±0.1	0.07±0.01
HU	7.15±0.26	6.75±0.54	-	21±0.45	1.9±0.01
Bb	7.79±0.72	7.35±0.01	2.3±0.23	13±0.1	0.04±0.02
D D	8.34±0.24	7.65±0.15	4.8±0.1	15±0.1	1.80±0.1

Table 3: Characteristics of the soil samples textures from the various study areas (mean ± SD)

	Textures		
	Sand	Silt	Clay
Bk	60±0.9	12±0.98	28±0.91
HU	52±1.7	18±0.1	30±2
Bb	76±0.26	16±0.1	8±0.1
D D	74±0.1	16±0.1	10±0.1

Soil texture is an important soil characteristic that influences storm water infiltration rates. Soil samples collected from Babile contained large amount of sand (76%) and soil samples collected from Haramaya contained small amount of sand (52%). The clay content of the soil samples ranged from 8% (Babile) to 30 % (Haramaya). The silt content of the soil samples ranged from 12% (Bako) to 18 % (Haramaya) as indicated in Table 3.

Extractable P, NO_3^- and K Using Conventional Soil Testing Methods: The available Phosphorus (P) estimated by conventional soil-testing methods was shown in (Table 5). The available P ranged from 1.64 mg kg^{-1} for Bako District to 29.07 mg kg^{-1} for Dire Dawa Administrative Council using the Olsen method. The available P ranged from 1.71 mg kg^{-1} for Bako District to 10.91 mg kg^{-1} for Dire Dawa Administrative Council using the Bray I method. The concentrations of available P with both Olsen and Bray I extraction methods for acidic soils were low. According to [39] the available P contents of the soils ranged from very low to very high. The greatest available P in Dire Dawa was likely due to the high organic matter (OM) content of the soil (Table 5). Soil organic matter influences the concentration of P in soil solution by desorbing P from the adsorption site through ligand exchange reaction with the organic ligands [18]. The lowest available P (1.64) was observed in strongly acidic soil (Bako Districts). This may be due to the inherent P deficiency of the soil and P fixation with iron (Fe) and aluminum (Al) by the favorable acidic soil reaction. The low contents of available P observed in some of the soils of the studied areas were in agreement with the studies by different authors [8, 20].

The amount of NO_3^- extracted ranged from 1.32 mg kg^{-1} (Babile) to 21.37 mg kg^{-1} (Dire Dawa) and the amount of K extracted ranged from 0.29 mg kg^{-1} (Babile) to 38.60 mg kg^{-1} (Bako) (Table 6).

Table 4: Regression results of NPK concentrations extracted by universal and convection extractants for four selected areas of soil

Chemical extractants	Nutrient extracted	Regression equations	Coefficient of Determination (R^2)
2M KCl	Nitrate (NO_3^-)	Y= 0.052X - 0.009	R^2 = 0.997
0.02M $SrCl_2$	Nitrate(NO_3^-)		
M3	Nitrate (NO_3^-)		
Kelowna	Nitrate (NO_3^-)		
Olsen	Phosphorus (P)	Y = 0.290X + 0.069	R_2 = 0.995
Bray I	Phosphorus (P)		
0.02M $SrCl_2$	Phosphorus (P)		
M3	Phosphorus (P)		
Kelowna	Phosphorus (P)		
1M NH_4OAc	Potassium (K)	Y = 0.41X + 0.023	R_2 = 0.996
0.02M $SrCl_2$	Potassium (K)		
M3	Potassium (K)		
Kelowna	Potassium (K)		

Table 5: Soil available phosphorus (P) (mg/ kg) extracted by conventional method (mean ± S.D)

		Extractants used	
Soil sample sites	Nutrients	Olsen	Bray I
Bako	P	1.64±0.23	1.71±0.23
Haramaya	P	27.87±0.76	8.86±0.92
Babile	P	7.33±1.03	2.52±0.13
Dire Dawa	P	29.07±1.02	10.91±1.4

Table 6: Soil available NO_3^- and exchangeable K (mg kg^{-1}) extracted by conventional method (mean ± S.D)

	Soil sample site			
	Bako	Haramaya	Babile	Dire Dawa
NO_3^-(2MKCl)	16.11±0.94	10.51±0.52	1.32±0.52	21.37±0.60
K(1M NH4OAc)	38.60±0.66	1.83±0.14	0.29±0.13	0.86±0.06

Table 7: Soil available phosphorus (P) (mg kg^{-1}) extracted by universal extractants (mean ± S.D)

		Extractants used		
Soil sample sites	Nutrient	0.02M $SrCl_2$	M 3	Kelowna
Bk	P	5.76±0.28	2.20±0.23	7.39±0.62
HU	P	8.83±0.20	20.65±0.79	12.26±1.22
Bb	P	7.01±0.93	8.18±1.16	7.15±0.73
DD	P	16.38±0.94	55.8±1.07	25.66±0.91

Extractable P, NO_3^- and K in the Soils After Applying Universal Extractants: The available P estimated by the three methods is shown in (Table 7). The order of magnitude of P extraction differed according to the soil types and extractants used. In acidic soil, the amount of available P extracted by Kelowna was greater than M3 and 0.02M $SrCl_2$ in (Bako District), whereas the amount of available P extracted by Mehlich 3 was greater for neutral and alkaline soils. High extraction efficiency of Mehlich 3 for available P in neutral and alkaline soil was supported by [20] who reported that Mehlich 3 is the best extractant for available P determination under high pH condition.

The amount of NO_3^- determined by the three universal extractants is shown in (Table 8). Large amount of NO_3^- was extracted from soil by Kelowna extractant. The high extraction efficiency of Kelowna for NO_3^- was supported by [9]. The order of magnitude of extraction for strongly acidic soil was Kelowna > 0.02M $SrCl_2$>Mehlich 3. However, the order of magnitude for NO_3^- extraction differed according to the soil types and extractants used. Among the universal extractants tested for NO_3^- determination, lower amounts of NO_3^- were determined by Mehlich 3. This is possibly because the Mehlich 3 solution contains NO_3^- salts, which interfere the extraction efficiency of the method during extraction of available NO_3^- from soil. The lower efficiency of the Mehlich 3 was supported by [20]. This confirmed that the method used is not suitable for determination of NO_3^- in some selected soils types in Ethiopia.

Exchangeable potassium (K) values estimated by the three methods are shown in (Table 9). Lower exchangeable potassium (K) was extracted from the Babile District by all methods. The concentration of K extracted varied widely with the method used (Table 9). The order of magnitude of extracted K in different soils were 0.02 M $SrCl_2$>Mehlich 3 > Kelowna. The order of magnitude of extracted K using Mehlich 3 and Kelowna (Mehlich 3 > Kelowna) is supported by [16]. Each extractant desorbed a different portion of K. In acidic soils, 0.02M $SrCl_2$ and Mehlich 3, were desorbed a large portion of K in comparison to the Kelowna extractant tested.

Analysis of Variance with Equal Replication of P, NO_3^- and K Extracted by 0.02 M $SrCl_2$, M3 and Kelowna: The relationships among P, NO_3^- and K extractants were tested for statistical significance as shown in Table 10.

Table 8: Soil available nitrate (NO_3^-) (mg kg^{-1}) extracted by universal extractants (mean ± S.D)

		Extractants used		
Soil sample Sites	Nutrient	0.02M $SrCl_2$	M 3	Kelowna
Bk	NO_3^-	1.53±0.40	0.28±0.02	22.48±0.40
HU	NO_3^-	8.40±0.40	3.16±0.06	30.34±0.60
Bb	NO_3^-	0.96±0.26	0.22±0.06	25.35±0.60
DD	NO_3^-	20.01±0.03	4.36±0.60	34.73±0.60

Table 9: Soil exchangeable potassium (K) (mg kg^{-1}) extracted by universal extractants (mean ± S.D)

		Extractants used		
Soil sample Sites	Nutrient	0.02M $SrCl_2$	M 3	Kelowna
Bako	K	67.10±1.3	20 .70±0.80	19.5±0.35
Haramaya	K	0.39±0.01	2.02±0.03	1.89±0.12
Babile	K	0.08±0.01	0.26±0.02	0.75±0.02
Dire Dawa	K	0.46±0.01	0.90±0.02	0.86±0.02

Table 10: Correlation values among the different extractants for the determination of P, NO_3^- and K, from soils

Nutrients	Methods/extraction used	0.02M $SrCl_2$	M3	Kelowna
P	Olsen	0.78*	0.82**	0.78*
	Bray I	0.85**	0.89**	0.85**
	M3	0.99***	1.00	0.99***
NO_3-	0.02M $SrCl_2$	1.00	0.99***	0.98***
	0.02M $SrCl_2$	1.00	0.90***	0.98***
	Kelowna	0.98**	0.93***	1.00
	2M KCl	0.70*	0.55^{ns}	0.73*
K	1M NH_4OAc	0.99***	0.99***	0.99***
	0.02M $SrCl_2$	1.00	0.99***	0.99***
	Kelowna	0.99***	0.99***	1.00

*, **, *** Significant at P ≤ 0.05, 0.01 and 0.001, ns = non significant

The Olsen method, which is the conventional method for available P determination in basic soil, was significantly correlated with 0.02M $SrCl_2$, Mehlich 3 and Kelowna extractants. However, the greatest correlation (r = 0.82) at P < 0.01 was found between the Olsen method and Mehlich 3 (Table 10). The Bray I method, which is the conventional method for available P determination in acidic soil, was significantly correlated with 0.02M $SrCl_2$, Mehlich 3 and Kelowna extractants. However, the greatest correlation (r = 0.89) at P < 0.01 was found between the Bray I method and Mehlich 3 (Table 10). The results obtained from this study concur with the findings reported by other researchers such as [19, 35 and 43].

The 2M KCl method, which is the conventional method for nitrate (NO_3^-) determination, was significantly correlated with 0.02M $SrCl_2$ and Kelowna extractants.However, among the universal extractants that was tested for NO_3^- determination, the greatest correlation (r = 0.73) at P < 0.05was found between 2M Kcl and Kelowna as shown in (Table 10). In view of universal extractants, the Kelowna and 0.02M $SrCl_2$extractants can be suitable for determination of NO_3^- in some selected Ethiopian soils.

Although the universal extractants removed different quantities of K from the soils, the amounts determined by each extractants were highly correlated with each other (Table 10).

From the data given in (Table 9), it can be summarized that all extractants show highly significant correlation with the 1M NH_4OAc method, yet the greatest correlation values were r = 0.99 at P < 0.001 between 1M NH_4OAc and the three methods. The high correlation value (r = 0.99) at P < 0.001 between Mehlich 3 and 1M NH_4OAc was supported by the researcher [20]. Similarly, the 0.02M $SrCl_2$extractant shows highly significant correlation with 1M NH_4OAc method and was supported by [20] and Kelowna was highly significant correlation with 1M NH_4OAc. Therefore, Mehlich 3, 0.02M $SrCl_2$ and Kelowna extractants can be used as methods for K determination from the economic point of view considering universal extractants.

Summary and Conclusion: Results from this study showed that the amount of P determined using universal extractants, such as 0.02M $SrCl_2$, Mehlich 3 and Kelowna, were generally well correlated with the conventional methods. However, high correlation was found between Olsen method and Mehlich 3. Therefore, the Mehlich 3, 0.02M $SrCl_2$ and Kelowna extractants were efficient in determining the available P in some selectedsoil types of Ethiopia. The implication is that Mehlich 3, 0.02M $SrCl_2$ and Kelowna could replace the conventional methods for available P determination from soils.

The amount of NO_3^- determined using universal extractants differed according to the soil types and extractants used. Among the universal extractants tested for determination of NO_3^-, the 0.02M $SrCl_2$ and Kelowna extractants could easily replace the convectional soil testing methods in some selected Ethiopian soils.

Results from this study also showed that the amounts of exchangeable K determined using universal extractants such as 0.02M $SrCl_2$, Mehlich 3 and Kelowna were generally well correlated with each other and NH_4OAc method. Therefore, these methods could easily replace the conventional method (NH_4OAc) for determining the K from soil.

In general, the 0.02M $SrCl_2$ and Kelownashowed significant correlation with all macronutrients. Mehlich 3 performed even better with phosphorus and potassium macronutrients except NO_3^-. This indicates that both 0.02M $SrCl_2$ and Kelowna can serve as universal extractants for the macronutrients considered in this study. For the most effective universal extractants tested in this study, greenhouse and field correlation and calibration studies are needed to confirm these results for the important crops.

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