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Levels of selected metals in wild edible plant *Embelia schimperi* Vatke fruit under different agro-ecological zones, Ethiopia

Zelalem Pawlos[1], Bhagwan Singh Chandravanshi[1,*], Weldegebriel Yohannes[1] and Asamene Embiale[2]

[1]Department of Chemistry, College of Natural and Computational Sciences, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia
[2]Department of Chemistry, Woldia University, P.O. Box 400, Woldia, Ethiopia
*Corresponding author's E. mail: bscv2006@yahoo.com

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A B S T R A C T

Fruit is one of the major dietary sources of various antioxidant phytocompounds for humans. The aim of this study was to determine the levels of macro and trace metals in *Embelia schimperi* Vatke, a wild edible plant fruit and its underlying soil samples collected from three different areas (Chencha, Dega Damot and Fiche) of Ethiopia. Levels of selected metals (Ca, Mg, Fe, Mn, Zn, Cu, Cd, Pb) were determined by microwave plasma-atomic emission spectrometry. Known weight of oven-dried *Embelia schimperi* Vatke fruit samples were wet-digested using 3 mL of (69–72%) HNO_3 and 1 mL of (70%) $HClO_4$ for (2:30 h) at temperature of (270 ^oC) and its soil with 3 mL of (69-72%) HNO_3, 1 mL of (70%) $HClO_4$ and 1 mL of (35%) HCl for 2 h at temperature of 240 ^oC. The validity of the optimized procedure was evaluated by the analysis of spiked samples whose recovery was in the range of 90.5–108%. The mean concentration range (mg/kg) of metals in *Embelia schimperi* Vatke fruit samples were K (13290–17972), Mg (681–855), Fe (337–774), Ca (4789–5380), Zn (22.8–35.8), Cu (10.2–14.9), Mn (36.4–48.2), Pb (4.42–5.21) and Cd (0.25–0.33), respectively. In the soil samples, highest concentration was observed for Fe, followed by Ca, K, Mn and Mg, while lowest concentration was shown by Cd which was below detection limit in all the soil samples. One way analysis of variance indicated a significant difference between levels of metals (K and Mg). Bioaccumulation factors exhibited significantly higher accumulation of K and Ca from the soil to the fruits, but for other elements, it was less than 1. The results revealed that the soil properties significantly affected the metal levels in the fruits.

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Capsule Summary: The levels of selected essential and non-essential metals in a wild edible plant fruit, *Embelia schimperi* Vatke, and its underlying soil samples collected from three different areas of Ethiopia were determined by microwave plasma-atomic emission spectroscopy. Pb content was higher than the WHO permissible level while Cd was present at trace level, which need to be monitored regularly.

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INTRODUCTION

Plants are the main sources for animal and human nutrition. Depending on different climates and cultures a number of plant species grown naturally in the forests or in uncultivated land are used for different purposes. From past to present a number of wild edible plants have been used for food (Seyoum et al., 2015). Edible wild plants are defined as the "plants which as whole or their any part (roots, leaves or fruits) are acceptable for eating by urban and rural communities." A plant considered to be an edible one could also have poisonous, medicinal, bitter, woody, and hairy parts. Therefore, it is very important to identify which plant is an edible one (Shaheen et al., 2017). Wild edible plants are the plants which are free of cost and can be found at any place we are living. These wild edible plants may be seasonal and can have more nutritional value than those grown in particular field in particular environmental conditions. These are fresh and more tasteful than those arranged on shelves in stores and cultivated (Shaheen et al., 2017).

Fruits are one of the major dietary sources of various antioxidant phytocompounds for humans. Our daily diet plays a key role in healthy aging and preventing chronic disease including obesity, diabetes, cardiovascular diseases, cancer, and osteoporosis. Edible wild plant fruits play significant role providing nutrient food supplement. Fruits collected by local people from natural forests are often seen for sell in the market. Many valuable fruits which are familiar to certain areas or to certain communities are unknown to others (Valvi et al., 2014).

Indigenous people are endowed with knowledge of seasonal availability of wild edible plants and implications to climate change adaptations. Different food types (fresh or dishes, sauces, snacks and juices, carbohydrates and minerals) are obtained from the parts of these plants (leaves, seeds and nuts, fruits, roots, tubers and barks) (Tebkew et al., 2018).

Various reports also noted that many wild edible plants are nutritionally rich and can supplement nutritional requirements, especially vitamins and micronutrients. Nutritional analysis of some wild food plants demonstrates that in many cases the nutritional quality of wild plants is comparable and in some cases even superior to domesticated varieties (Seyoum et al., 2015; Balemie and Kebebew, 2006; Lulekal et al., 2011; Assefa and Abebe, 2011; Dirres, 2016). Wild edible plants are also important to cultural identity, provide essential sources of nutrients and vitamins as well as much seasonal dietary variety. Many wild edible leaves, fruits and nuts are good sources of carbohydrates, protein, fat, vitamins, and minerals that may be deficient in common diets. Most of the wild plant foods have a good proportion of some nutrients and bioactive ingredients, and can make a significant contribution to daily nutrient intake, especially for the rural communities and those of low social classes (Loki and Ndyomugyenyi, 2016).

Wild edible plants are important elements of natural ecosystem and agriculture. These are often considered as green factories that nature has provided us. They are playing important role in maintenance of balance agricultural productivity. Utilization of wild edible plants as food sources is a chance to ensure the food security and reduce malnutrition problems (Shaheen et al., 2017).

It has been considered that wild and cultivated fruits are rich sources of various vitamins, minerals, fibres and polyphenols which provides several health benefits and consumption of fruits and green leafy vegetables reduces the risk of several diseases like diabetes, cancer, coronary heart disease, neurodegenerative ailment and aging as well (Islary et al., 2016).

In the western part of Ethiopia, specifically in Benishangul-Gumuz region, households (mainly the indigenous ones) were found to resort to depend on wild foods as a coping mechanism to overcome extremely severe poverty and food insecurity conditions. Coping mechanisms are one of the defining components of household resilience because having more coping strategies means having more probability of mitigating food insecurity (Guyu and Muluneh, 2015).

Plants get nutrient from environmental compartment (soil, water and air). But they are not perfectly selective only to essential nutrients; they may take up metals that are toxic even at low level. Metals present in the soil vary in degree of mobility. Their bioavailability is regulated by soil properties and interactions between them (Hassani et al., 2015). Changes in the chemical properties of the soils highly affect their availability for plants. With increasing pH, contents of organic matter and clay; solubility of most metals are decreased due to their increased tendencies for adsorption (Takáč et al., 2009). Plants may take up metals and accumulate them in their edible and non-edible parts in quantities high enough to cause risks both to animals and human beings consuming these metal rich plants (Mustapha and Adebayo, 2014). In particular, heavy metals pose a great health risk to all living organisms upon long term exposures (Alemayehu Abiye et al., 2011) because of their non-biodegradability, long biological half-lives and potential to accumulate in different body parts. Even at low concentration levels they have damaging effects to man and animals since there is no good mechanism for their elimination from the body (Takáč et al., 2009; Mustapha and Adebayo, 2014; Lokeshappa et al., 2012).

Embelia schimperi Vatke belongs to family *Myrsinaceae.* It is a climbing shrub which reaches the height of 2-13 meters. The fruit, 5-8 mm in diameter, is orange yellow, reddish-green to red in color when ripening (Figure 1). Each fruit often has one seed that has a diameter of 4.5-7 mm. It is brown in color with irregular orange markings when ripen (Debebe et al., 2015).

Fruit decoction is useful in fevers and diseases of chest and skin. Infusion of roots is used for cough and diarrhea. Aqueous extract of the fruits showed antibacterial and anti-fertility activities. Seeds were found to possess antibiotic and anti-tubercular properties. A gum obtained from the plant is used as a warming remedy in the treatment of dysmenorrheal. Decoction of the leaves is used as a blood purifier (d'Avigdor et al., 2014). *Embelia schimperi* Vatke is

traditionally used as an antibacterial and anthelminthic remedy, especially against tapeworm and diarrhea.

Assessments of heavy metals contents in different plants, which are used as food source, have been conducted in the world including Ethiopia. Recently some studies have been done on the mineral contents of fruits of cactus pear (Aregahegn et al., 2013), fennel (Endalamaw and Chandravanshi, 2015), banana, grape, guava, mandarin and orange (Yami et al., 2016), apple (Jemaneh and Chandravanshi, 2021) and seeds of korarima (Mekassa and Chandravanshi, 2015) and fenugreek (Hagos and Chandravanshi, 2016) cultivated in Ethiopia. Few studies have also been published on the determination of the metal content of wild edible plants in Ethiopia (and in a wild edible plant fruits of *Ficus sur* Forssk grown in Ethiopia) (Boke et al., 2015; Haile et al., 2018; Pawlos et al., 2021). Since such study is not getting a serious attention in Ethiopia, it is very important to determine the level of the essential and toxic metals in the other wild edible plants. Therefore, the present study is focused on the determination of levels of the accumulated heavy metals in the wild edible plant *Embelia schimperi* Vatke fruits and in the soils of the plant.

The main objective of this study was to determine the levels of macro (K, Mg and Ca), micro (Zn, Fe, Cu, Cr and Mn) and toxic (Pb and Cd) metals in *Embelia schimperi* Vatke fruits. Specifically (i) to determine the soil electrical conductivity, pH and organic matter content to check the bioavailability of metals in the plant, (ii) to determine the metal contents of *Embelia schimperi* Vatke fruits and its corresponding soil, (iii) to compare the levels of metals in *Embelia schimperi* Vatke fruits with WHO standards, and (iv) to determine the correlation of the analyzed metals in the plants and the corresponding soils.

MATERIAL AND METHODS

Apparatus and equipment

Polyethylene plastic bags was used to pack the harvested *Embelia schimperi* Vatke fruits and soil samples. A drying oven (Digitheat, J.P. Selecta, S.a., Spain) was used to dry the fruit and soil samples. A blending device (Moulinex, France) was used to ground and homogenize the samples. A digital analytical balance (Mettler Toledo, Model AG204, Switzerland) with ± 0.0001 g precision was used to weigh the samples. A 250 mL round bottomed flasks fitted with reflux condensers were used in Kjeldahl (England) apparatus to digest the dried and powdered fruit and soil samples. A refrigerator (Hitachi, Tokyo, Japan) was used to keep the digested sample until analysis. A microwave plasma-atomic emission spectrometry (MP-AES) (model 4200 Agilent, USA) was used for the determination of the metals (Na, Mg, Mn, Pb, K, Ca, Fe, Zn, Cu, Cr, Cd) in the samples. A ceramic mortar and pestle was used for grinding and homogenizing the soil samples. Conductivity and pH meter (Romania) was used for measuring electrical conductivity and pH of the soil samples.

Reagents and chemicals

Reagents used were all analytical grade. (69-72%) HNO_3 (Spectrosol, BDH, England) and 70% $HClO_4$ and (36-38%) HCl (Aldrich, A.C.S. Reagent, Germany) were used for digestion of fruit and soil samples. Strontium nitrate (98%, Aldrich, Muwaukee, USA) was used to avoid refractory interference (for realizing calcium and magnesium from their phosphates). Stock standard solutions containing 1000 mg/L, in 2% HNO_3, of the metals, Mg, Mn, Pb, K, Ca, Fe, Zn, Cu and Cd (Buck Scientific Puro-Graphic^{tm}, USA) were used for preparation of calibration standards and in the spiking experiments. Distilled water was used throughout the experiment.

Description of sampling sites

The fruit and soil samples were collected from Fiche (Oromiya region), Dega Damot (Amahara region) and Chencha (South Nations Nationality People Region), Ethiopia. The selection of these places was based on two reasons. First, wild edible plant *Embelia schimperi* Vatke is mostly available in these regions and second, this plant is mostly taken by human beings (usage) in these regions. The geographical locations (latitude, longitude and elevation) of sampling sites are given in Table 1.

Collection and preparation of fruit samples

The fruits of *Embelia schimperi* Vatke plants were collected manually using vinyl gloves for protecting hands. The bruised portions were removed and the remaining samples were packed in the polyethylene bags and transported to the analytical laboratory. The fruit samples were washed with tap water and then with double distilled water to eliminate adsorbed dust and particulate matters. The fruits were cut and chopped into small pieces using plastic knife to facilitate drying. The samples were air-dried for five to six days and further dried in a hot air oven at 50-60 ^oC for 24 h to remove moisture and maintain constant mass. The dried samples were ground into powder using commercial mortar and pestle and sieved to 0.425 mm mesh size. The sieved samples were stored in the polyethylene bags and kept in desiccators until the time of digestion.

Collection and preparation of soil samples

The soil samples were collected from the base of uprooted plant by auger and properly labeled and packed in polyethylene bags. Each soil sample was air dried at ambient temperature for three days and ground into powder using mortar and pestle and sieved to 0.425 mm mesh. The sieved soil samples were stored in the polyethylene bags and placed in desiccators until the time of digestion.

Soil pH

Soil pH was measured in a suspension (1:2.5, w/v) of the soil and distilled water. 5 g of air-dried soil was weighed and

Table 1: Geographical location, elevation and distance from Addis Ababa of sampling sites

Site	Latitude	Longitude	Elevation (m)	Distance from Addis Ababa (km)
Fiche	9°48′N	38°44′E	2738	126.2
Dega Damot	11°05′N	37°25′E	1917	552
Chencha	6°15′N	37°34′E	2732	478.2

Table 2: Attempted digestion procedure for 0.5 g of *Embelia schimperi* Vatke fruit sample

Volume ratio (HNO_3:$HClO_4$)	Digestion temperature (°C)	Digestion time (h)	**Observations**
1:1 (2 mL)			Clear yellow
2:1 (3 mL)			Clear light yellow
1:2 (3 mL)	240	3	Clear light yellow
2:2 (4 mL)			Clear light yellow
3:1 (4 mL)			**Clear colorless solution**
	180		Clear yellow
3:1 (4 mL)	210	3	Clear light yellow
	240		Clear light yellow
	270		**Clear colorless solution**
		1:30	Clear yellow
3:1 (4 mL)	270	2	Clear light yellow
		2:30	**Clear colorless solution**
		3	Clear colorless solution

The bold font indicates optimum condition

transferred to a 100 mL beaker to which 12.5 mL distilled water was added. The mixture was stirred and the pH was measured after allowing the suspension to stand for 10 min at room temperature.

Electrical conductivity of soil

Electrical conductivity of the soil samples was measured in suspension (1:2.5 w/v) of the soil and distilled water. 5 g of air-dried soil was weighed and transferred to a 100 mL beaker to which and 25 mL distilled water was added. The mixture was stirred and allowed to stand for 15 min at room temperature and the electrical conductivity was measured.

Soil organic matter

Soil organic matter content was determined using the method of loss on ignition. 5 g of the soil sample of the plant, which dried in oven at 100 °C for 15 min, was accurately weighed in to a pre-weighed crucible. The crucible with soil was placed in a muffle furnace and heated at 520 °C for 3:30 h. The sample was taken from the furnace and placed in desiccators to cool. The sample was reweighed and the percentage organic matter content was calculated.

Optimization of digestion procedure for fruit sample

A 0.5 g of powdered and homogenized fruit sample was weighed and transferred to 250 mL of round bottom flask. To this, different volumes of HNO_3, $HClO_4$ at specified proportions (v/v) was added and digested at different temperatures 150, 180, 210, 240, 270 and 300 °C for different duration of time (60, 90, 120, 150 and 180 min). The optimized procedure was determined based on the formation of clear colorless solution. The digested solution was allowed to cool and 5 mL of distilled water was added to dissolve the precipitate formed on cooling and gently swirled and filtered into 50 mL volumetric flask through Whatman number 42 filter paper. The clear solution was diluted up to 50 mL with distilled water and stored for analysis by MP-AES. The results of the digestion procedure are given in Table 2.

Optimization of digestion procedure for soil samples

A 0.5 g of powdered, sieved and homogenized soil sample was weighed and transferred to a 250 mL round bottom flask. To this, different volumes of HCl, HNO_3 and $HClO_4$, at specified proportions (v/v) was added and digested at different temperatures 150, 180, 210, 240, 270 and 300 °C for different duration of time (60, 90, 120, 150 and 180 min). The optimized procedure was determined based on the usage of lesser reagent volume, shorter digestion time and reasonable mild temperature for obtaining clear and colorless solutions of the resulting digests. The digested solution was allowed to cool and 5 mL of distilled water was added to dissolve the precipitate formed on cooling and gently swirled and filtered into 50 mL volumetric flask. The clear solution was diluted up to 50 mL with distilled water and stored for analysis by MP-AES. The results are given in Table 3.

Table 3: Attempted digestion procedure for soil (the bold font indicates optimum condition)

Volume ratio (HNO_3:$HClO_4$:HCl)	Digestion temperature (°C)	Digestion time (h)	Observations
1:1:1 (3 mL)			Clear yellow
2:1:1 (4mL)			Clear yellow
1:2:1 (4 mL)			Clear yellow
1:1:2 (4 mL)	240	3	Clear light yellow
2:2:1 (5 mL)			Clear light yellow
1:2:2 (5 mL)			Clear light yellow
2:1:2 (5 mL)			Clear light yellow
3:1:1 (5 mL)			**Clear colorless solution**
	180		Clear yellow
3:1:1 (5 mL)	210		Clear yellow
	240	3	Clear light yellow
	270		**Clear colorless solution**
3:1:1 (5 mL)	270	1:30	Clear colorless solution
		2	**Clear colorless solution**

Table 4: Recovery test results for fruit sample

Metal	Conc. in sample (mg kg^{-1})	Amount added (mg kg^{-1})	Conc. in the spiked sample (mg kg^{-1})	Amount recovered (mg/kg)	(%) Recovery
Mg	781	390	1191	410	105±2
Mn	36.4	18.2	54.4	17.9	98.9±2.1
Fe	774	387	1180	406	105±1
Cu	14.9	7.45	21.9	7.05	94.6±2.3
Zn	35.8	17.9	53.9	18.1	101±3
Cd	0.33	0.165	0.50	0.17	106±4
K	13290	2658	15692	2403	90.4± 6.4
Ca	4789	958	5795	1006	105±1
Pb	5.21	2.60	7.61	2.40	92.3±1.6

Table 5: The value of pH, electrically conductivity (mSm^{-1}) and organic matter (%) of the *Embelia schimperi* Vatke plant soil

Area	pH ± SD	EC ± SD (mSm^{-1})	OM ± SD (%)
Chencha	6.33± 0.07	16.4 ± 0.32	18.6 ± 0.49
Dega Damot	5.59 ± 0.02	11.6 ± 0.25	13.7 ± 0.34
Fiche	5.82 ± 0.03	7.93 ± 0.21	15.5 ± 0.34

Digestion of fruit samples

A 0.5 g of powdered and homogenized fruit sample was weighed and transferred to 250 mL of round bottom flask. To this 4 mL of 3:1 (v/v) of HNO_3 and $HClO_4$ was added and digested at 270 °C for 2:30 h. The digested solution was allowed to cool and 5 mL of distilled water was added to dissolve the precipitate formed on cooling and gently swirled and filtered into 50 mL volumetric flask through Whatman no. 42 filter paper. The clear solution was diluted up to 50 mL with distilled water. The fruit sample was digested in triplicate. Digestion of a reagent blank was also performed in parallel with the samples. All the solutions were stored in tightly capped polyethylene bottles and stored in a refrigerator until analysis. The solutions were used to determine concentrations of K, Ca, Mg, Fe, Mn, Cu, Zn, Cr, Pb and Cd by MP-AES.

Digestion of soil samples

A 0.5 g of powdered, sieved and homogenized soil sample was weighed and transferred to a 250 mL round bottom flask. To this, 5 mL of 3:1:1 ratio of HNO_3, HCl and $HClO_4$ were added digested at 270 °C for 2 h. The digested solutions were allowed to cool and 5 mL of distilled water were added to dissolve the

Table 6: Levels metals ($mgkg^{-1}$), (mean ± SD, n = 3) in fruit samples

Metal	Concentration of heavy metals ($mgkg^{-1}$), (mean ± SD, n = 3)		
	Chencha	Dega Damot	Fiche
K	13290±9.0	14665±9.5	17972±9.7
Ca	4789 ± 10.1	49991 ± 9.1	5380 ±11.5
Mg	781 ± 5.4	681 ± 4.3	855 ± 4.32
Mn	36.4 ± 2.4	37.8 ± 2.1	48.2 ± 1.6
Fe	774 ± 3.5	643 ± 3.4	337 ± 2.4
Cu	14.9 ± 1.2	13.6 ± 0.5	10.2 ± 1.6
Zn	35.8 ± 1.3	22.8 ± 1.2	30.1 ± 2.3
Pb	4.47 ± 0.10	4.42 ± 0.05	5.21 ± 0.06
Cd	0.33 ± 0.01	0.23 ± 0.02	0.025 ± 0.01

Table 7: Concentration of metals ($mgkg^{-1}$), (mean ± SD, n = 3) in the soils

Metal	Concentration of heavy metals ($mgkg^{-1}$), (mean ± SD, n = 3) in the soils		
	Chencha	Dega Damot	Fiche
K	1466 ± 6.4	2209 ± 6.8	1323 ± 9.6
Mg	1338 ± 8.1	1235 ± 9.1	1061 ± 9.4
Ca	4228 ± 9.9	2265 ± 12	1343 ± 8.8
Mn	2462 ± 11	1131 ± 10	1526 ± 11
Fe	99956 ± 16	96454 ± 17	97642 ± 15
Cu	34.4 ± 3.0	33.4 ± 2.0	60.4 ± 3.1
Zn	105 ± 2.0	143 ± 4.1	149 ± 3.1
Pb	9.76 ± 0.80	30.5 ± 0.2	16.0 ± 0.7
Cd	ND	ND	ND

ND-not detected

Table 8: Metal concentration (mg/kg) the *Embelia schimperi* Vatke plant and its soil samples

Metal	Range of metal concentration (mg/kg)	
	Fruit	Soil
K	13290-17972	1323-2209
Mg	681-855	1061-1388
Ca	4789-5380	1243-4228
Mn	36.4-48.2	1131-2462
Fe	337-774	49956-97642
Cd	0.25-0.33	ND
Pb	4.42-5.21	9.76-30.5
Cu	10.2-14.9	33.4-60.4
Zn	22.8-35.8	105-149

ND-not detected

precipitate formed on cooling and gently swirled and filtered into 50 mL volumetric flask through Whatman no. 42 filter paper. The clear solution was diluted up to 50 mL with distilled water. The soil sample was digested in triplicate. Digestion of a reagent blank was also performed in parallel with the samples. The solutions were used for the analysis of the soil metal concentrations for, K Ca, Mg, Fe, Cu, Zn, Mn, Cr, Pb and Cd by MP-AES.

Calibration of MP-AES instrument

A 100 mg/L standard solution was prepared from standard stock solutions that contained 1000 mg/L. These 100 mg/L were diluted with distilled water to obtain four working standards for each metal of interest K, Ca, Mg, Mn, Cd, Cr, Zn, Pb, Fe, and Cu. The instrument was calibrated using four series of working standards. Calibration curves were prepared by

plotting working standards concentration versus their corresponding emission intensity to determine the concentration of metals in the sample solution. The correlation coefficients for all the metals were > 0.998 which indicated good linearity of the calibration curves.

Recovery test

A recovery test was carried out by spiking pre-analyzed samples. Each of the target elements was spiked at 50% of the initial concentrations of the respective element in the original sample. The efficiency of the optimized procedure was checked by adding the known concentration of each metal to 0.5 g fruit sample. For the recovery test 195, 9.1, 194, 3.74, 8.94, 0.08, 664, 239, and 2.60 µL of 1000 mg/L Mg, Mn, Fe, Cu, Zn, Cd, K, Ca, and Pb were spiked to a 0.5 g fruit sample, respectively. The same digestion process was followed as for the samples. Each recovery test for the sample was performed in triplicates. Each sample was determined for their respective spiked metals by microwave plasma-atomic emission spectrometry. The results are given in Table 4.

Statistical analysis of data

The data obtained was analyzed by a computer program using Microsoft Excel 2007. One-way analysis of variance (ANOVA) ($p = 0.05$) was used to assess the statistical level of significance of the difference between and within the data obtained with samples from different sources. Pearson correlation coefficient was used assess association between metals.

RESULTS AND DISCUSSION

Soil properties

Plants get nutrient from environmental compartment (soil, water and air). The bioavailability of metals in the plant depends on a number of physical and chemical factors of the soils. These include: pH, organic matter content and electrical conductivity (Boke et al., 2015). The values of soil pH, % organic matter (OM) and electrical conductivity (EC) of the soils of the three different sites are presented in Table 5. The result showed that the soil of *Embelia schimperi* Vatke plant were acidic. Hence, metals are more mobile in the soil.

The higher the soil organic matter content, the higher the ability of that soil to retain metals within it. The result of analysis showed that the highest % organic matter was obtained in the soil from Chencha and the lowest was obtained in soil from Dega Damot. Thus the metals are more retained in the soil from Chencha than the soil from other sites. Therefore, the bioavailability of metals in soil for the plant species becomes low when the organic content of the soil is high due to the adsorption reaction of metals on it. According to the study the bioavailability of metals in soil for the plant species is given by the following increasing order; Dega Damot > Fiche > Chencha.

Most plants grow best in slightly acidic soils (pH 6.0-7.0). In this pH range, nearly all plant nutrients are available in optimal amounts. Soils with a pH below 6.0 are more likely to be deficient in some available nutrients. Ca, Mg and K are especially deficient in acid soils (Nweke and Nsoanya, 2013). Metal solubility tends to increase at lower pH and most of the mobility of metals is reduced with increasing soil pH because of the precipitation as insoluble hydroxides, carbonates and organic complexes. Usually the intensity of root uptake of metal by plants decreases with increasing soil pH. Low soil pH value determines the activity of many metal ions in the water contained in the pores of the soil, affecting their bioavailability (Boke et al., 2015). The result showed that the soil pHs in three study areas are within the range of 5.54 to 6.95, which categorizes the soils under weakly acidic soils. According to Nweke and Nsoanya (2013) most plants grow best in this pH range. Therefore, all the plant nutrients are available to the plant in optimal amounts.

Soil electrical conductivity (EC) is a useful indicator in managing agricultural systems. EC directly affects plants growing in the soil or media. EC range of 0-1 dS/m indicates good soil health. Soils that have EC 1:1 of less than 1 dS/m is considered to be nonsaline. Soils that have EC 1:1 of more than 1 dS/m is considered to be saline. Important microbial processes, such as nitrogen cycling, production of nitrous gases and other N oxide gases, respiration, and decomposition of organic matter are affected. Populations of parasitic nematodes and loss of nitrogen can be higher in these soils (Ratul et al., 2018). The result showed that the EC of the soils in three study areas are within the range of 7.84 to 71.40 ms/m, therefore values of EC indicating that soil environment is good for the plant growth.

Levels of metals in the fruit samples

The levels of metals K, Ca, Mg, Fe, Mn, Cu, Zn, Pb and Cd determined in samples are reported as mean of three measurements with corresponding standard deviation for each metal in a given sample. The results are given in Table 6. K content in the three study areas was in the range of 13290 mg/kg in Chencha up to 17972 mg/kg in Fiche. Similarly, levels of Mg were within a range of 681 mg/kg in Dega Damot up to 855 mg/kg in Fiche, whereas Ca levels ranged between 4789 mg/kg to 5380 mg/kg in Chencha and Fiche, respectively. Among the studied essential micronutrient, highest concentrations of Mn (48.2 mg/kg) in Fiche, Fe (744 mg/kg) in Chencha, Zn (35.8 mg/kg) in Chencha and Cu (14.9 mg/kg) in Chencha were observed. On the other hand, toxic metals Cd (0.025-0.33 mg/kg) and Pb (4.42-5.21 mg/kg) were detected in all three studied area. The highest concentration of Pb and Cd were obtained in fruit from Fiche and Checha, respectively.

Levels of metals in the soil samples

The metal levels in the soil samples of *Embelia schimperi* Vatke plant are given in Table 7. The level of Fe (96454-

Table 9: Transfer factor (TF) of metals from soil to *Embelia schimperi* Vatke plant

Metal	Transfer factor (TF) values		
	Chencha	Dega Damot	Fiche
K	9.06	6.18	13.6
Mg	0.58	0.55	0.81
Ca	1.13	1.20	4.01
Mn	0.01	0.03	0.03
Fe	0.0077	0.0067	0.0035
Cu	0.43	0.41	0.17
Zn	0.34	0.16	0.20
Pb	0.46	0.45	0.32
Cd	-	-	-

Table 10: Pearson correlation coefficients between metal concentrations in ESV samples

	K	Mg	Ca	Mn	Fe	Cu	Zn	Pb	Cd
K	1.000								
Mg	0.6221	1.000							
Ca	0.9986	0.5796	1.000						
Mn	0.9835	0.7536	0.9725	1.000					
Fe	-1.000	-0.6169	-0.9989	-0.9822	1.000				
Cu	-1.000	-0.6243	-0.9984	-0.984	0.9999	1.000			
Zn	-0.2185	0.6281	-0.27	-0.0381	0.2249	0.2158	1.000		
Pb	0.9407	0.8509	0.9213	0.9866	-0.9384	-0.9416	0.1257	1.000	
Cd	-0.5836	0.2727	-0.626	-0.4269	0.5890	0.5814	0.9199	-0.2734	1.000

Table 11: Analysis of variance (ANOVA) between samples of *Embelia schimperi* Vatke fruit

Parameters	Metals compared at 95% confidence level							
	K	Ca	Mg	Fe	Mn	Cu	Zn	Pb
$F_{critical}$	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14
$F_{calculated}$	696	2.74	14.1	4.58	3.15	0.23	0.23	1.25

99956 mg/kg) was highest compared to other metals in all the soil samples. K, Mg, Ca and Mn were also present in appreciable amount in all the soils. The levels of Zn (105-149 mg/kg) and Cu (33.4-60.4 mg/kg) were much lower than the other metals. The level of toxic metal Pb was in the range (9.76-30.5 mg/kg) while the other toxic metal Cd was below the detection limit in all the soil samples.

Comparison of metals concentration

The range of metal concentrations of the *Embelia schimperi* Vatke plant and its soil samples from three study areas are given in Table 8. The results showed that except K and Ca all the metal concentrations in soil are higher than fruit of *Embelia schimperi* Vatke. The levels of Fe in the soil samples are much higher than in the fruit samples.

Accumulation factor of metals from soil to plant

Metal transfer factor from soil to plants is a key module of human exposure to metals via food chain. Transfer factor of metals is essential to investigate the human health risk. Transfer of metals from soil to plant was studied using transfer factor (TF). It was calculated as a ratio of concentration of a specific metal in plant to the concentration of same metal in soil, both represented in same units. Higher TF values (≥1) indicate higher absorption of metal from soil by the plant and higher suitability of the plant for phytoextraction and phytoremediation. On the contrary, lower values indicate poor response of plants towards metal absorption and the plant can be used for human consumption (Mirecki et al., 2015). The transfer factors of the metals are given in Table 9.

The TF of K (6.18-13.6) is highest followed by Ca (1.13-4.01). The higher TF (>1) of K and Ca indicate that the plant also absorbs these two metals from other sources than soil such as water and air. The TF of Fe (0.0035-0.0077) is

the lowest followed by Mn (01-0.03) which indicates that Fe and Mn are highly retained in the soil and not available for absorption to the plant. The TF of other metals are <1 which indicates the other metals (Mg, Cu, Zn and Pb) easily absorb to the plant. The lower TF indicates poor response of plants towards metal absorption from the soil and the plants can be used for human consumption.

Correlation coefficient of metals

Pearson's correlation was performed to investigate relationship between metal concentrations in the plant. The high correlation coefficient (r) (near +1 or -1) means a strong relation between two variables, and low correlation around zero means no relationship between them at a significant level of 0.05% level, it can be strongly correlated, if r > 0.7, whereas r values between 0.5 to 0.7 shows moderate correlation between two different parameters (Rakesh Sharma and Raju, 2013). The correlation coefficients for metals in the fruit are given in Table 10. The results showed that Pearson correlation coefficients between metal concentrations in *E. schimperi* Vatke fruit samples exhibit strong, medium and weak association of metals.

Analysis of variance

In this study, fruit samples of wild edible plant *Embelia schimperi* Vatke and its soil were collected from three different areas from randomly selected forest where they are widely available. During this processes a number of random errors may be introduced in each aliquots and in each replicate measurements. Therefore, depending upon the type and nature of results, a statistical method is used to check whether there is contribution from random errors for difference in results of analysis or not. One-way analysis of variance (ANOVA) is used to perform the statistical analysis with fruit as independent and concentration of the metals as dependent variable to test whether there are significant differences between means of fruit samples at the stated confidence level. The result of the analysis is depicted in Table 11. The results obtained from one way ANOVA indicate that there is a significant difference between means of metals at 95% confidence level for K and Mg. The results also showed that insignificant variation at 95% confidence level between mean concentration of Ca, Fe, Mn, Cu, Zn, Pb in the fruit samples.

Comparison of metal concentration with literature

Table 12: Comparison of the levels of the metals found in *Embelia schimperi* Vatke fruit with the reported values in literature

Wild edible plant	Metals (mg/kg, dry weight)									Reference
	K	Mg	Ca	Fe	Zn	Mn	Cu	Pb	Cd	
Ficus sur	-	-	-	-	-	-	5.20	0.70	0.90	(Haile et al., 2018)
Blackberry		-	-				6.45	5.75	2.52	
Dovyalis abyssinica	-	-	-			-	4.72	1.20	0.20	
Eriosema cordifolium	-	-	1288	-	44.0	-	BDL	BDL	BDL	(Boke et al., 2015)
Pachyeymbium sacculatium	-	-	6214	-	156	-	BDL	BDL	BDL	
Commiphora confusa Vollesen	-	-	1447	-	49.4	-	BDL	BDL	BDL	
Physalis peruviana	-	-	24.4	-	31.3	-	BDL	BDL	BDL	
Ficus sur Forssk	13029	787	4580	444	24.7	14.1	7.47	4.62	1.15	(Pawlos et al., 2021)
Embelia schimperi Vatke	15309	772	5053	585	29.6	40.8	12.9	4.70	0.27	Present study

BDL = below detection limit

Table 13: Comparison of results of present study metals concentration with WHO/FAO Joint Codex Alimentarius Commission maximum permissible levels (mg/kg) (Codex Alimentarius Commission, 2011)

	Zn	Cu	Pb	Cd	Mn	Fe	Mg	K	Ca
WHO/FAO Joint Codex Alimentarius Commission	100	40	1	0.3	-	-	-	-	-
Embelia schimperi fruit	29.6	12.9	4.70	0.27	40.8	585	772	15309	5053

Comparison of metal concentration in fruit of *Embelia schimperi* Vatke with literature values of other wild edible plants are summarized in Table 12. There is lack of literature on the levels in wild edible plants. But two authors have studied on other wild edible plants for some essential and toxic metals. There is only report on K, Mg, Fe and Mn in the literature, which showed that K and Fe are higher in the present study while level of Mg is comparable to the reported value. The level of Ca of the present study is within the range of Ca reported in the literature. The level of Zn of the present study is lower than the reported values while the level of Cu of present study is higher than the reported values. The levels of toxic metals Pb and Cd of the present study are within the range reported in the literature.

Comparison with WHO/FAO

The levels metals found in the present study were compared with the maximum permissible levels set by WHO/FAO Joint Codex Alimentarius Commission (2011) (Table 13). The results showed that all the metals except Pb are within the maximum permissible levels set by WHO/FAO Joint Codex Alimentarius. Since Pb is highly toxic metal eating the wild plant *Embelia schimperi* Vatke fruit regularly may results in health problem.

CONCLUSIONS

The present study determined levels of essential (K, Ca, Mg, Fe, Zn, Cu, Mn) and toxic metals Cd and Pb in the wild edible plant *Embelia schimperi* Vatke fruits and their corresponding soil from three different area of Ethiopia. The levels of metals were determined using MP-AES. Concentration of Cd was below the detection limit in all soil samples. The investigation of the metal levels revealed that for most of the metals determined, there was a direct relationship between the levels in the fruit and the soil on which the plant was grown. The study also showed that the metals were present at different concentrations in the samples from different sites. Comparable results were found with some of the values reported in the literature and for some of the metals the concentrations slightly exceeded the permissible levels by WHO/FAO. The bioavailability of the metals in plant was checked by analysis of soil pH, soil organic matter and soil electrical conductivity. The study showed that the bioaccumulation factors exhibited significantly higher accumulation of K and Ca from the soil and for others, it was < 1, which revealed that soil properties have significant effect on the metal levels in the fruits.

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