

## Diversity in antioxidant properties and mineral contents of *Allium paradoxum* in the Hyrcanian forests, Northern Iran

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**Abstract.** Khodadadi S, Nejadsattari T, Naqinezhad A, Ebrahimzadeh MA. 2015. Diversity in antioxidant properties and mineral contents of *Allium paradoxum* in the Hyrcanian forests, Northern Iran. *Biodiversitas* 16: 281-287. The knowledge about variation of antioxidant properties from local medicinal plant can be achieved by investigating all natural habitats of it. To reach this goal, a comprehensive survey on eight populations of *Allium paradoxum* (M. B.) G. Don, was conducted in the Hyrcanian forests. *A. paradoxum* (Amaryllidaceae) is a perennial, local plant, native to the northern Iran. Different parts of it, is largely used in food preparation and traditional medicine. Plants were collected randomly from different altitudes and forest sites of Iranian northern provinces ranging from west to east (Guilan, Mazandaran and Golestan Provinces). Samples were divided into aerial and bulbous parts. The antioxidant activities of the extracts were investigated with 1, 1-diphenyl-2-picrylhydrazyl (DPPH) and reducing power assays. Total flavonoid content was determined by a colorimetric aluminum chloride method. The highest antioxidant activities and flavonoid contents in *A. paradoxum* were related to Varaki and Zarinabad sites (Mazandaran province) with relatively higher humidity, in the central part of the Hyrcanian area and in altitudinal range between 462-860 m asl. The content of total phenolics in the extracts was determined according to the Folin-Ciocalteu reagent method, and calculated as gallic acid equivalents (GAE). With respect to total phenolic contents, aerial parts of plants of Jahannama, the lowest elevation site (Golestan province), had the highest amount. Elemental composition (Fe<sup>++</sup>, Mn<sup>++</sup>) and total sulphur were also determined using Atomic Absorption Spectroscopy and digestion method, respectively. Higher contents of two elements, particularly Fe, and total sulphur can be found in bulbous part of Zarinabad and Kiasar populations (Mazandaran province) compared to other sites. The results of the current study indicated that there is a remarkable and significant variation of antioxidant activities among different studied populations of *A. paradoxum* in the Hyrcanian forests.

**Key words:** *Allium paradoxum*, antioxidant activity, medicinal plant, mineral contents

### INTRODUCTION

The natural antioxidants present in dietary plants have great importance in favoring health and resistance to oxidative stress in humans (Dimitrios 2006). The total antioxidant potential (TAP) in food products is related to the different molecules present in foods. Antioxidant capacities are considerably modulated by numerous factors including biological and environmental factors, as well as their interaction (Lisiewska et al. 2006; Moore et al. 2006). Plant materials contain various forms of antioxidants. Phenolic compounds are found in plants, have multiple biological effects. Flavonoids and other phenolics have been suggested to play a protective role against damages caused by disease (Kähkönen et al. 1999; Mammadov et al. 2011).

Nutrients play a significant role in improving productivity and quality of plants. Sulphur supply influences bulb yield, plant dry matter, bulb pungency and flavor intensity in *Allium* crops (Durenkamp and De Kok 2004). Sulphur insufficiency will result in the loss of plant health, the plant's resistance to environmental stress, and in decreased food quality and safety (De Kok et al. 2002; Durenkamp and De Kok 2004). Micronutrients are

involved in numerous biochemical processes and adequate intake of certain micronutrients related to the prevention of deficiency diseases (Ebrahimzadeh et al. 2011).

The genus *Allium*, a member of Amaryllidaceae family, contains more than 900 species (APG III 2009; Li et al. 2010; Tojibaev et al. 2014). The most important diversity source of the genus is considered in the mountainous areas of southwest and central Asia including the territory of Iran (Fritsch and Friesen 2002). *Allium* comprises many economical, ornamental and medicinal species that have been used as a remedy for treatment of certain diseases (Fritsch and Friesen 2002; Putnokoy et al. 2013). Among the different medicinal plants, some endemic species may be used for phytochemicals with significant antioxidant capacities and health benefits (Exarchou et al. 2002).

*Allium paradoxum* (M.B.) G. Don is a perennial species of shady woods in the Caucasus, northern Iran and neighboring parts of central Asia (Vvedenskii 1935; Wendelbo 1971; Stearn 1992). This plant is one of locally vegetables that was known as "Alezi", and is used as a healthy vegetable in raw or cooked form for people who are living in northern provinces of Iran. The populations of the plant are obvious during late February to early April in

the Hyrcanian forests. The Hyrcanian forest is a temperate deciduous forest ecosystem in the southeastern part of the Caucasus biodiversity hotspot, that are located in three northern provinces of Iran, namely, Guilan, Mazandaran and Golestan with a total surface area of 1.84 million hectares (Bobek 1951; Takhtajan 1986; Naqinezhad et al. 2015).

So far, most studies about *Allium* relating to cysteine sulphoxides and alliinase activity (Krest et al. 2000; Fritsch and Keusgen 2006), antioxidant activity of several *Allium* members (Yin and Cheng 1998) or have focused only on whole species such as *A. paradoxum* (Ebrahimzadeh et al. 2010; Nabavi et al. 2012; Elmi et al. 2014), *A. sativum* L. and *A. cepa* L. (Benkeblia 2005; Lawrence and Lawrence 2011), *A. ursinum* L. (Putnoky et al. 2013). Ghasemi et al. (2015) investigated properties of garlic under selenium and humic acid treatments. The results of their study show the positive effects of applied treatments. Ebrahimzadeh et al. (2010) reported trace elemental analysis in *A. paradoxum* and among them, higher contents related to Fe and Mn. There is no report about total sulphur content in *A. paradoxum*.

The purpose of this study is to provide the first report about variation in phytochemical properties of *A. paradoxum* and potential sources of natural habitats in Northern provinces of Iran. Moreover, we aim to estimate total sulphur and trace element (Fe, Mn) contents in the studied populations.

## MATERIALS AND METHODS

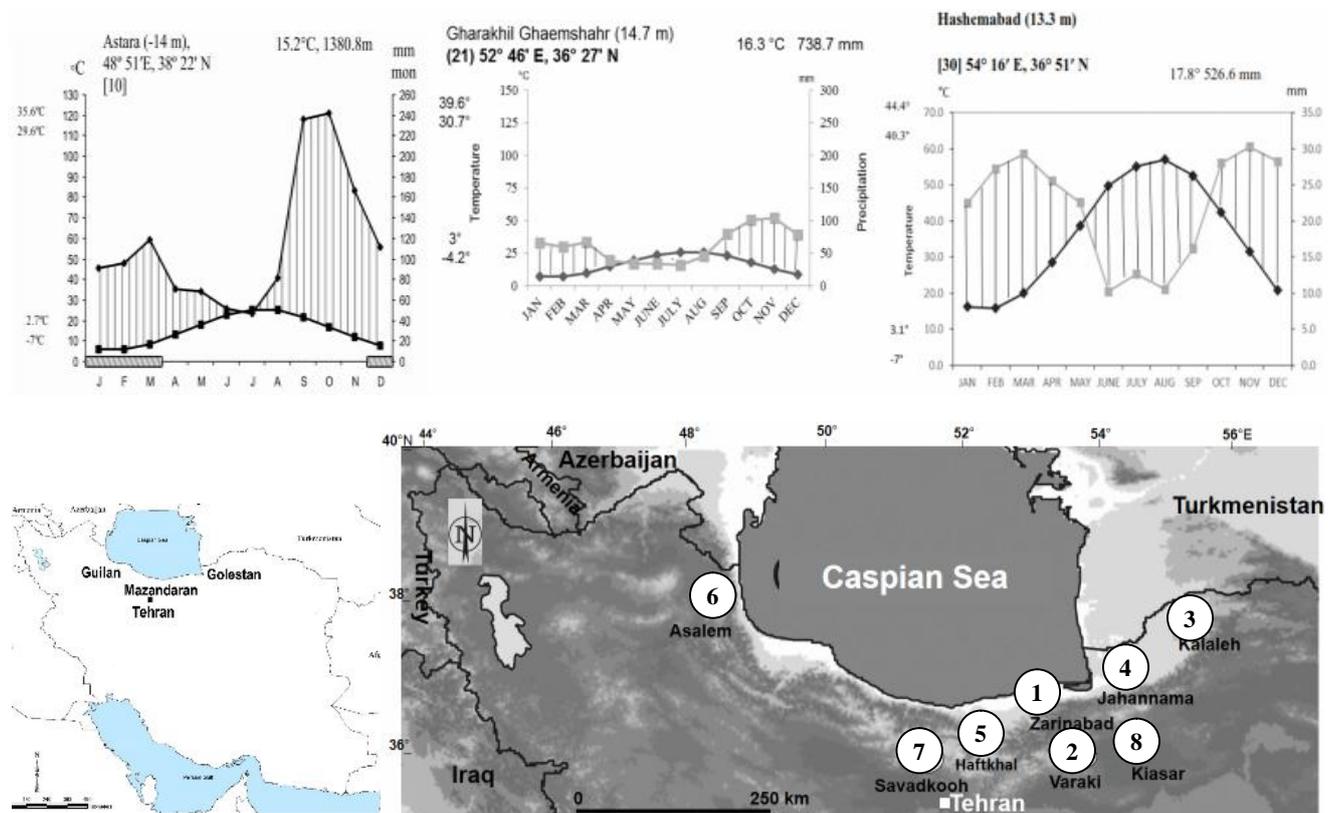
### Chemicals

Barium chloride, 1,1-diphenyl-2-picryl hydrazyl (DPPH), Magnesium nitrate, Perchloric acid and potassium ferricyanide were purchased from Sigma Chemicals Co. (USA). Gallic acid, Quercetin and Ferric chloride were purchased from Merck (Germany).

### Study areas, plant material and preparation of extract

We selected eight forest sites (Zarinabad, Varaki, Kalaleh, Jahannama, Haftkhal, Asalem, Savadkooh and Kiasar) from northern provinces of Iran namely Guilan, Mazandaran and Golestan. These sites were located in the Hyrcanian area along an altitudinal gradient from 198 to 1980 m asl. (Figure 1, Table 1). Three Meteorological stations, i.e. Astara in Guilan province, Gharakhil in Mazandaran province and Hashemabad in Golestan province were the closest stations to the current studied sites. According to bioclimatic classification of Iran (Djamali et al. 2011), the climate of area varies from temperate oceanic in Astara (Guilan) to Mediterranean pluviseasonal oceanic in Hashemabad site (Golestan).

Samples were randomly collected from aforementioned sites during March to April 2014. The materials (aerial and bulbous parts) were dried at room temperature for two



**Figure 1.** Studied sites of *Allium paradoxum* populations in the Hyrcanian forest. Climatic diagrams are shown from the nearest stations in each of three provinces (from left: Guilan, Mazandaran and Golestan, respectively).

**Table 1.** The characteristics of eight sites for *Allium paradoxum* sampling.

Forest site	Province	Longitude	Latitude	Altitude (m a.s.l)
Zarinabad	Mazandaran	E 053°12 19.2	N 36°29 44.4	462
Varaki	Mazandaran	E 53°07 29.6	N 36°17 13.9	860
Kalaleh	Golestan	E 055°36 52.1	N 37°24 35.2	698
Jahannama	Golestan	E 54°07 23.5	N 36°44 37.8	198
Haftkhal	Mazandaran	E 53°23 59.2	N 36°17 22.1	897
Asalem	Guilan	E 048°49 07	N 37°39 32.8	1200
Savadkooh	Mazandaran	E 52°48 29.9	N 36°06 27.8	1980
Kiasar	Mazandaran	E 053°36 39.5	N 36°06 27.8	1825

weeks (bulbs were oven dried at 35°C, for 2 days). Dried materials were coarsely ground (2-3 mm) before extraction. Each part (100 g) was extracted by percolation using methanol/water (80/20 w/w) for 24 h at room temperature. The extracts were then separated from the sample residues by filtration through Whatman No.1 filter paper. The extractions were repeated three times. The resultant extracts were concentrated in a rotary evaporator until crude solid extracts were obtained which were then freeze-dried for complete solvent removal (Ebrahimzadeh et al. 2010). The yields of each sample were presented in Tables 2 and 3.

#### DPPH radical-scavenging activity

The stable 1, 1-diphenyl-2-picrylhydrazyl radical (DPPH) was used for determination of free radical-scavenging activity of the extracts (Yamaguchi et al. 1998; Nabavi et al. 2009). Different concentrations of each extract (100, 200, 400, 800 and 1600 µg mL<sup>-1</sup>) were added, at an equal volume, to a methanolic solution of DPPH (100 µM). After 15 min at room temperature, the absorbance was measured at 517 nm. Methanol with DPPH was used as control. The experiment was repeated three times. Vitamin C and butylated hydroxyanisole (BHA) were used as standard controls. IC<sub>50</sub> values denote the concentration of sample which is required to scavenge 50% of DPPH free radicals. The scavenging activity was estimated based on the percentage of DPPH radical scavenged as the following equation: Scavenging effect (%) = [(A<sub>0</sub> - A<sub>s</sub>)/A<sub>0</sub>] × 100, where A<sub>0</sub> is the absorbance without extract and A<sub>s</sub> is the absorbance of extracts or standards.

#### Reducing power determination

The reducing power of extracts was determined according to the method of Yen and Chen (1995) (Nabavi et al. 2008). Different amounts of each extract (50-800 µg mL<sup>-1</sup>) in water were mixed with phosphate buffer (2.5 mL, 0.2 M, pH 6.6) and potassium ferricyanide [K<sub>3</sub>Fe (CN)<sub>6</sub>] (2.5 mL, 1%). The mixtures were incubated for 20 minutes at 50°C. 2.5 mL of trichloroacetic acid (10%) was added to the mixture to stop the reaction, then centrifuged at 3000 rpm for 10 min. The supernatant of solution (2.5 mL) was mixed with distilled water (2.5 mL) and FeCl<sub>3</sub> (0.5 mL, 0.1%), and the absorbance measured at 700 nm. Vitamin C was used as positive control.

#### Total phenol and flavonoid contents

Total phenolic contents were determined by the Folin-Ciocalteu reagent method (Ebrahimzadeh et al. 2008; Singleton et al. 1999). The extract samples (0.5 mL) were mixed with 2.5 mL of 0.2 N Folin-Ciocalteu reagent for 5 min and 2.0 mL of 75 g l<sup>-1</sup> sodium carbonate then added. The absorbance was measured at 760 nm after 2 h of incubation at room temperature. The standard curve was prepared by 0, 50, 100, 150, 200 and 250 mg mL<sup>-1</sup> solutions of gallic acid in methanol: water (50: 50, v/v). Results were expressed as mg gallic acid equivalents (GAE) g<sup>-1</sup> of extract. Total flavonoid content was determined by a colorimetric method (Chang et al. 2002; Ghasemi et al. 2009). 0.5 mL solution of each plant extract in methanol was separately mixed with 1.5 mL of methanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1 M potassium acetate and 2.8 mL of distilled water and left at room temperature for 30 min. The absorbance of the reaction mixture was measured at 415 nm with a double beam spectrophotometer (Perkins Elmer AAS 100). The calibration curve was prepared by preparing quercetin solutions at concentrations 12.5 to 100 mg mL<sup>-1</sup> in methanol. The total flavonoids were expressed as mg quercetin equivalent (QE) g<sup>-1</sup> of extract powder.

#### Determination of total sulphur content and mineral analysis

Total sulphur of aerial parts and bulbs were measured in the digest as described by Quin and Wood (1976). Samples (0.1 g) were analyzed for sulphur after magnesium nitrate and perchloric digestion. Barium chlorate was added to the mixture and it was left overnight, following which the absorbance of the final reaction mixture was measured at 420 nm (Ghasemi et al. 2015). Results are expressed as µg in g dry matter. Iron and manganese were analyzed in the samples. Briefly, the properly dried and ground plant samples were ash-dried overnight at 400-420°C in a Vitreosil crucible. The inorganic residue was kept in a desiccator until needed for analysis. Two-tenths of a gram of ash was dissolved in a 1: 3 mixture of hydrochloric and nitric acids (Han et al. 2008) diluted to 50 mL with distilled water and analyzed with an atomic absorption spectrometer (Perkins Elmer AAS 100) (Wellesley, MA). The results were expressed in mg g<sup>-1</sup> of sample.

#### Statistical analysis

Experimental results are expressed as means ± SD. All measurements were replicated three times. The data was analyzed by one-way ANOVA and the means separated by Tukey s post-hoc test (P < 0.05).

## RESULTS AND DISCUSSION

#### DPPH radical-scavenging activity

Scavenging of the stable DPPH radical is a widely used method to evaluate the free radical scavenging ability of various samples (Ebrahimzadeh et al. 2009). Results of our study show that scavenging effect of samples is increased by increasing their concentrations. Among these samples,

the aerial parts generally had the strongest radical scavenging activity than bulbous parts (Tables 2 and 3). The lowest  $IC_{50}$  (the highest activity) for DPPH radical-scavenging activity was  $0.96 \mu\text{g mL}^{-1}$  for Varaki aerial parts (Mazandaran). The  $IC_{50}$  values for Vitamin C and BHA were  $3.7 \pm 0.1$  and  $29.3 \pm 5.9 \mu\text{g mL}^{-1}$ , respectively.

### Reducing power of extracts

The reducing power capacity of compounds may serve as a significant indicator of its potential antioxidant activity (Meir et al. 1995). This reducing power capacity was determined using a  $Fe^{3+}$  to  $Fe^{2+}$  reduction system. The amount of  $Fe^{2+}$  complex can be monitored by measuring the formation of Perl's Prussian blue at 700 nm. Increasing absorbance at 700 nm indicates an increase in reductive ability. Figures 2 and 3 show the dose-response curves for the reducing power of extracts (at 50-800  $\mu\text{g mL}^{-1}$  concentration). The reducing power of extracts also increased with increasing their concentrations. There were significant differences between extracts and vitamin C ( $P < 0.01$ ). The highest reducing power activity was observed in aerial parts of Varaki site (1.32, at 800  $\mu\text{g mL}^{-1}$ ). The aerial part extracts showed higher reducing power than bulb extracts.

### Extraction yield, total phenol and flavonoid contents

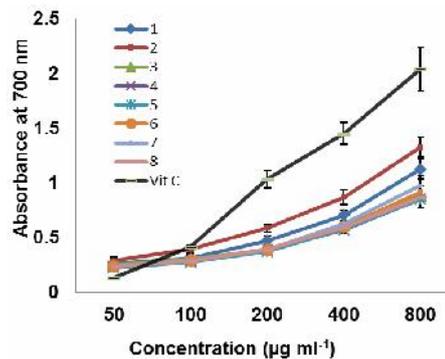
The extraction yield of different fractions of *A. paradoxum* was varied from 4.7 to 26.1% (Tables 2 and 3). The extraction of aerial parts resulted in the higher amount of total extractable compounds than bulb extracts. The amount of total phenolics varied in different populations and ranged from  $5.7 \pm 0.5$  to  $112.4 \pm 7.5 \text{ mg GAE g}^{-1}$  of extract. The highest total phenolic contents were  $112.4 \pm 7.5$  and  $111.2 \pm 5.4 \text{ mg GAE g}^{-1}$  of extract, bulbs and aerial parts of "Jahannama" and "Varaki" samples, respectively. The content of flavonoid varied from 1.3 to  $294.33 \pm 11.3 \text{ mg QE g}^{-1}$  of extract powder (Tables 2 and 3). Aerial part extracts had significantly higher flavonoid contents than bulb extracts. Plants of "Zarinabad" site (Mazandaran province) showed the highest amount of flavonoid contents followed by Varaki ( $294.33 \pm 11.3$  and  $173 \pm 4.4$ , respectively).

### Total sulphur and mineral analysis

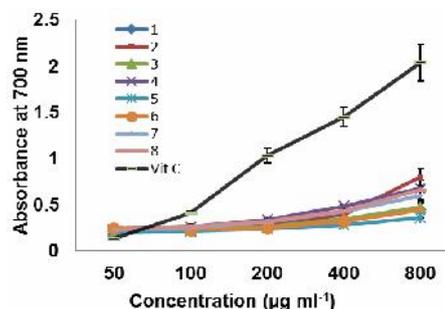
The results of the current study showed that bulbous parts had higher total sulphur than aerial parts. According to Tables 2 and 3, total sulphur content in *A. paradoxum* ranged from 69-210  $\mu\text{g}$  in g dry matter. The highest sulphur content was found in bulbs of Kiasar (Mazandaran province). Results of elemental analysis were presented in Tables 2 and 3. The comparative study showed that the bulbous part of Zarinabad sample had the maximum value of Fe and Mn contents.

### Discussion

Investigation on antioxidant properties with particular concern of geographical distribution of plant populations has become of interest of current relevant studies (Pisoschi and Negulescu 2011). This kind of research can be also very important particularly on endemic and other restricted-range plants.



**Figure 2.** Reducing power of aerial parts extracts of *Allium paradoxum* populations. Vitamin C used as control. Numbers show studied sites. For names of 1-8 see Figure 1.



**Figure 3.** Reducing power of bulbous parts extracts of *Allium paradoxum* populations. Vitamin C used as control. Numbers show studied sites. For names of 1-8 see Figure 1.

Antioxidant agents of natural origin have attracted special interest because of their free radical scavenging abilities. Because of this, the antioxidant activities of *A. paradoxum* populations were determined by two spectrophotometric methods. The DPPH method rely on the reaction of 1, 1-diphenyl-2-picrylhydrazyl radical with an antioxidant molecule. It decolorizes the DPPH solution and the degree of color change is proportional to amount of the antioxidants (Saeed et al. 2012). In reducing power test, the presence of the reductants in the solution causes the reduction of the  $Fe^{3+}$ /ferricyanide complex to the ferrous form. Therefore,  $Fe^{2+}$  can be monitored by absorbance measurement at 700 nm. In the present study, the results of two antioxidant tests showed that the aerial part extract of Varaki population in Mazandaran province had higher antioxidant action than other populations. Based on altitudinal range of current survey (198- 1980 m a.s.l) (Table 1), this site is located in the middle of the cited range.

Although phenolic acids and flavonoids are not essential for survival, may provide protection against a number of chronic diseases over the long term consumption (Bravo 1998). Variation of total phenol and flavonoids in our study area showed that the plant extracts of all populations had the potential for accumulating phenol and flavonoids. Bulbous part of Jahannama population (eastern part of our study area with low rainfall) possessed the

**Table 2.** Yield, total phenolic and flavonoid contents of methanolic extract, total sulphur and trace elements from aerial part of different populations of *Allium paradoxum* in Iran.

Parameters	Zarinabad	Varaki	Kalaleh	Jahannama	Haftkhal	Asalem	Savadkooh	Kiasar	F
Total phenol content (mg GAE g <sup>-1</sup> )	64.4 <sup>a</sup> ±3.2	111.2 <sup>b</sup> ±5.4	54.4 <sup>c</sup> ±3.2	62.6 <sup>af</sup> ±2.6	47.4 <sup>d</sup> ±3.6	56.4 <sup>c</sup> ±2.8	5.7 <sup>e</sup> ±0.5	60.6 <sup>f</sup> ±2.2	2325.84*
Flavonoid content (mg QE g <sup>-1</sup> )	294.3 <sup>a</sup> ±1.3	173 <sup>b</sup> ±4.4	80.3 <sup>c</sup> ±3.5	51.0 <sup>d</sup> ±1.3	31.7 <sup>e</sup> ±2.2	77.8 <sup>e</sup> ±3.4	61.3 <sup>f</sup> ±1.1	103.7 <sup>g</sup> ±5.1	29300.50*
DPPH radical scavenging, IC <sub>50</sub> (µg mL <sup>-1</sup> )	1.50 <sup>af</sup> ±0.01	0.96 <sup>b</sup> ±0.00	1.43 <sup>acf</sup> ±0.01	1.56 <sup>adf</sup> ±0.01	1.38 <sup>c</sup> ±0.01	1.46 <sup>acf</sup> ±0.01	1.66 <sup>df</sup> ±0.01	1.57 <sup>adf</sup> ±0.00	101.83*
Total sulphur (µg in g dry matter)	81 <sup>a</sup> ±3.2	99 <sup>b</sup> ±3.1	110 <sup>c</sup> ±5.2	120 <sup>d</sup> ±3.7	110 <sup>c</sup> ±5.1	69 <sup>e</sup> ±1.9	88 <sup>f</sup> ±2.3	120 <sup>d</sup> ±5.8	1056.80*
Fe (mg g <sup>-1</sup> )	0.93 <sup>a</sup> ±0.03	0.82 <sup>a</sup> ±0.03	3.35 <sup>bc</sup> ±0.11	3.19 <sup>bc</sup> ±0.17	0.54 <sup>a</sup> ±0.01	1.41 <sup>ab</sup> ±0.10	2.40 <sup>b</sup> ±0.16	0.77 <sup>a</sup> ±0.02	25.04*
Mn (mg g <sup>-1</sup> )	0.05 <sup>a</sup> ±0.01	0.05 <sup>a</sup> ±0.01	0.07 <sup>ab</sup> ±0.01	0.08 <sup>b</sup> ±0.01	0.03 <sup>ac</sup> ±0.00	0.05 <sup>a</sup> ±0.01	0.05 <sup>a</sup> ±0.00	0.04 <sup>ac</sup> ±0.00	7.50*
Extraction yield (%)	18	21.2	19.8	18.2	21.2	20.1	26.1	23.2	

Note: IC<sub>50</sub> of BHA was 29.3 ± 5.9 µg mL<sup>-1</sup>. Each value in Table 2 is represented as mean SD (n=3) and F-ratio (\*) based on one-way ANOVA of studied variables. Values in the same row followed by a different letter are significantly different (p<0.05).

**Table 3.** Yield, total phenolic and flavonoid contents of methanolic extract, total sulphur and trace elements from bulbous part of different populations of *Allium paradoxum* in Iran.

Parameters	Zarinabad	Varaki	Kalaleh	Jahannama	Haftkhal	Asalem	Savadkooh	Kiasar	F
Total phenol content (mg GAE g <sup>-1</sup> )	47.2 <sup>a</sup> ±2.1	46.8 <sup>a</sup> ±1.7	49.2 <sup>a</sup> ±2.2	112.4 <sup>b</sup> ±7.5	30.2 <sup>c</sup> ±1.5	36.4 <sup>d</sup> ±1.9	59 <sup>e</sup> ±1.6	80.8 <sup>f</sup> ±4.1	2088.90*
Flavonoid content (mg QE g <sup>-1</sup> )	4.3 <sup>a</sup> ±0.2	1.3 <sup>ac</sup> ±0.0	1.7 <sup>ac</sup> ±0.0	7.7 <sup>b</sup> ±1.2	4.0 <sup>a</sup> ±0.1	5.3 <sup>ab</sup> ±1.2	3.3 <sup>a</sup> ±0.0	6.0 <sup>ab</sup> ±0.2	11.93*
DPPH radical scavenging, IC <sub>50</sub> (µg mL <sup>-1</sup> )	2.32 <sup>acd</sup> ±0.01	3.19 <sup>abcd</sup> ±0.02	2.34 <sup>acd</sup> ±0.02	1.78 <sup>acde</sup> ±0.01	4.21 <sup>bcf</sup> ±0.02	2.89 <sup>abcd</sup> ±0.02	3.51 <sup>b</sup> ±0.02	1.72 <sup>acde</sup> ±0.01	14.67*
Total sulphur (µg in g dry matter)	120 <sup>a</sup> ±4.4	81 <sup>b</sup> ±1.2	120 <sup>a</sup> ±4.9	150 <sup>c</sup> ±6.6	180 <sup>d</sup> ±6.4	110 <sup>e</sup> ±5.7	112 <sup>e</sup> ±4.1	210 <sup>f</sup> ±6.4	5311.66*
Fe (mg g <sup>-1</sup> )	17.30 <sup>a</sup> ±0.24	2.50 <sup>b</sup> ±0.09	2.25 <sup>bcd</sup> ±0.13	2.80 <sup>bd</sup> ±0.18	0.92 <sup>c</sup> ±0.04	1.05 <sup>bc</sup> ±0.15	1.95 <sup>bcd</sup> ±0.18	1.43 <sup>bcd</sup> ±0.1	28.21*
Mn (mg g <sup>-1</sup> )	0.1 <sup>a</sup> ±0.01	0.05 <sup>a</sup> ±0.00	0.07 <sup>a</sup> ±0.00	0.06 <sup>a</sup> ±0.01	0.02 <sup>a</sup> ±0.00	0.02 <sup>a</sup> ±0.00	0.01 <sup>a</sup> ±0.00	0.05 <sup>a</sup> ±0.01	2.20
Extraction yield (%)	9.8	8.1	6.4	4.7	6.1	11.6	11.0	12.3	

Note: IC<sub>50</sub> of BHA was 29.3 ± 5.9 µg mL<sup>-1</sup>. Each value in Table 3 is represented as mean SD (n=3) and F-ratio (\*) based on one-way ANOVA of studied variables. Values in the same row followed by a different letter are significantly different (p<0.05).

highest amount of total phenol. In most measurements of the current experimental analysis, aerial parts had higher contents than bulbs that are compatible with the results of Ebrahimzadeh et al. (2010).

Minerals are usually divided in two groups macro- and micro- minerals (or trace elements), and also classified as either essential or nonessential, depending on whether or not they are required for human nutrition and have metabolic roles in the body (Reilly 2002). Sulphur content of plant varies from 0.03-2 mmol g<sup>-1</sup> dry weight (DW) in different species (Durenkamp and De Kok 2004). In the current study, total sulphur content of bulbs showed higher amounts than in aerial parts. Study of Ghasemi et al. (2015) showed that total sulphur of *A. sativum* is in higher amount than in *A. paradoxum*. Moreover, the results of our study revealed that iron concentration is higher than manganese. However, this result can be varied in aerial and bulbous parts. Fe and Mn play vital roles in biochemical processes (Ebrahimzadeh et al. 2010, 2011). Element composition differs strongly between plant organs (Minden and Kleyer 2013). Variability may also come from differences in size, age, ontogenetic state and reproductive status between plant individuals (Agren 2008).

The results of this study demonstrated variation of antioxidant properties and mineral contents in plant organs of *A. paradoxum* populations along the Hyrcanian forests. The results generally indicated that populations of *A. paradoxum* in Mazandaran province had good capacity to utilize in medicine and food industry. Further field studies are needed to explain precise correlation between variation of mentioned properties in *A. paradoxum* and the environmental factors.

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