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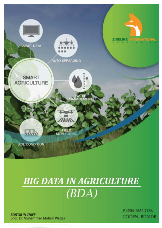

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RESEARCH ARTICLE

SEASONAL VARIATIONS IN ESSENTIAL TRACE ELEMENTAL STATUS OF SOLANUM NIGRUM L. COLLECTED FROM MOUNTAINOUS RANGE OF PAKISTAN

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ABSTRACT

Neglected and under-utilized plants could be a worthwhile substitute to the present-day crops. Many such species are well reported in literature being consumed by aborigines to overcome nutritional deficiencies. *Solanum nigrum* L. (Mako) is a wild herbaceous plant from family Solanaceae and is abundantly found in mountainous and sub-tropical areas of the Punjab, Pakistan. It has promising nutritive values and is adaptive to wide climatic conditions. However, environmental variations such as seasonal rainfall, fluctuations in temperature and soil pH can severely affect the uptake of trace elements from soil. Hence, current study was conducted to evaluate seasonal variations in essential trace elements of Mako plant. Biological triplicates of Mako plant were collected from Soone Valley during both seasons. Samples were subjected to spectrophotometry techniques to evaluate essential trace elements viz., Fe, Co, Cu, Mn and Zn in leaves, berries and root samples. Results showed significant variations in nutritional potential of plant parts during both seasons. Co, Cu and Mn contents in all plant parts were found higher during winter season as compared to contents measured during summer season. Fe contents showed abnormal behavior regarding accumulation in different plant parts. It was found maximum in leaves and root during winter season despite bearing the fact that alkaline pH limits Fe uptake and mobility. Zn content were found maximum in berries and leaves during summer season. Conclusively, it can be stated that *Solanum nigrum* L. possess good quantities of essential trace elements that fluctuate under different environmental conditions. Therefore, determination of elemental status of *Solanum nigrum* L. plant is recommended before utilizing its therapeutic potential to overcome certain nutrient's deficiency.

KEYWORDS

Nutrition, *Solanum nigrum* L., elemental composition, edible plant.

1. INTRODUCTION

Elements present in living entities carry out crucial metabolic reactions to maintain life related activities (Da Silva and Williams, 2001). Herbal medicines are the source of essential nutrients and therapeutic properties that are attributed to the presence of certain phytochemicals. Medicinal plants may behave differently under varying environmental conditions such as climate, physiochemical properties of soil and pattern of rainfall (Ncube et al., 2011). Plants harvest important nutrients directly from the soil such as turmeric is an accumulator of lead (Pb) and banana absorbs large quantities of potassium (K) from soil (Weerasinghe and Premalal, 2002). It is well established that curative abilities of many therapeutic plants used extensively in TMS (Traditional Medicine System) are dependent on essential trace elements in minute quantities (Prashanth et al., 2015).

An element is called as trace element if daily requirements are < 100 mg per day, while deficiency may lead to fatal disorders. Trace elements are essential for the body to perform different physiological, molecular and biochemical functions of the cell. Many such elements act as cofactors for enzymes mediating vital biochemical processes in the cell. Some are integral to structural stability of the cell as they stabilize structure of crucial proteins and enzymes (Al-Fartusie and Mohssan, 2017). Some of these elements control traffic of specific molecules in the cell by either altering the membrane structure or by binding to receptor site molecules thus regulating a number of important biological processes in the cell. Apart from maintaining physiological and structural integrity of the cellular components, imbalance in amount of trace elements may induce diseases because, their deficiency or toxicity in the body may stimulate alternative pathways leading to disorders (Prashanth et al., 2015; Dreosti, 2012). Hence, these have medical significance and can be determined by analytical methods using Atomic absorption spectrophotometer (AAS).

Table 1: Daily intake requirements of trace elements in adult human body

Trace Elements	Daily intake requirements by human body
Cu	1-2 mg per day
Fe	1-2 mg per day
Zn	15-20 mg per day
Co	0.0001 mg per day
Mn	2-5 mg per day
	Source: (Prashanth *et al.*, 2015)

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Daily intake requirements of these trace elements are listed in Table 1. Deficiency or toxicity of these trace elements may lead to fatal consequences. Some of these are reported in literature as follows: Iron (Fe) is absorbed from food in form of ferritin. Prolonged iron-deficiency can lead to anemia which can result in heart failure (Abbaspour et al., 2014). Zinc (Zn) is directly involved in protein and nucleic acid biosynthesis and degradation and is part of many hydrases, oxidoreductases and transcription factors involved in human metabolism. Hence, Zn-deficiency can result in reduced energy metabolism, acidosis and intoxication of alcohol products. Growth retardation, psychological disturbances and wound healing problems are also associated with Zn-deficiency (Chasapis et al., 2012).

Copper (Cu) is redox active and an essential nutrient. Cu-deficiency can result in severe structural malformations and persistent immunological and neurological aberrations in fetus and newborn. Likewise, Cu-toxicity can lead to liver dysfunction and neurological defects (Uriu-Adams and Keen, 2005). Cobalt (Co) is integral component of cobalamin (vitamin B12) which is crucial to maintain human health. Co-deficiency can lead to digestive disorders, cardiac failure, thyroid enlargement and neuromuscular maladies. But high dosage of Co may also be dangerous for normal metabolism of body (Mertz, 2012). Manganese (Mn) is an integral part of several enzymes including metalloenzymes and play significant role in oxidative phosphorylations and metabolism of cholesterol. Deficiency of Mn can cause anorexia, psychosis, headache and other disorders. Thus, analytical assessment of nutrients in consumable plants is important to avoid medical complications (Avila et al., 2013).

Table 2: Seasonal variations in trace element contents in different plant parts of *Solanum nigrum* L.

Trace Elements	Plant parts	Summer (mg/kg dry wt.)	Winter (mg/kg dry wt.)
Cobalt (Co)	Berries	27.67 ±5.86	49.67±5.51
	Leaves	22±1	41.33±1.53
	Root	12.97± 0.45	31±1
Copper (Cu)	Berries	104.17±5.53	144.67 ±9.24
	Leaves	105.17±6.007	174.5 ±10.5
	Root	103±2	130 ±10
Manganese (Mn)	Berries	40.5±0.4	63.33±7.64
	Leaves	9.5±0.1	13.63±1.21
	Root	15.03±0.15	23±1
Iron (Fe)	Berries	851±61.51	550.67±22.48
	Leaves	852.67±160.45	2251.33±131.71
	Root	1248.33±2.89	2375.83±105.01
Zinc (Zn)	Berries	24.67±0.58	1.47±0.45
	Leaves	24.5±0.5	19.55±0.18
	Root	12.28±0.072	18±1

Values are expressed as mean ± standard deviations of triplicate data

Solanum nigrum L. (Mako) is an important annual herb (sometimes perennial) belonging to family Solanaceae and is frequently found everywhere in Africa and Asia especially in arable lands. Red and black berries are consumed in porridges and soups, while, leaves are cooked as vegetable in many traditional cuisines (Akubugwo et al., 2007). Extract of *Solanum nigrum* L. has certain pharmacological properties; based on these properties it can be regarded as chemoprotective and antioxidative. It is reported to have good quantities of certain nutraceuticals, e.g. quercetin (Jimoh et al., 2010; Atanu et al., 2011). Nutritional potential of leaves and berries of this plant has been frequently reported in literature (Odukoya and Oshodi, 2018). However, there is little data on seasonal variations in nutritional potential of different parts of Mako plant. Therefore, following study was planned to study aforementioned aspect.

2. Materials and Methods

2.1 Geographical features of the selected site

Selected Jabba site (coordinates 32.626163, 72.370621 Decimal Degrees) is located in Soone Valley with an altitude of ~770 (MAMSL: Meters above sea level). Weather forecast data confirmed that average temperature during winter (10^{0}C) and summer (35^{0}C) is moderate. Maximum rainfall is noted during summer season while least is during winter season.

2.2 Sampling and determination of trace elements

Apparently homogenous triplicates of *Solanum nigrum* L. samples were collected from Soone Valley twice a year following stratified random sampling method. Soil pH was noted from the sampling site using pH meter. Soil pH during winter was measured 7.81 while during summer it lowered to 7.56. Plant samples were brought to the laboratory of Department of Botany, University of Agriculture, Faisalabad. All plant parts viz., berries, leaves and root were separated carefully. Dried samples were subjected to Atomic Absorption Spectrophotometer (AAS) to determine trace elements viz., Cu, Co, Fe, Mn and Zn using acid digestion method (Estefan et al., 2013).

2.3 Statistical analysis

Mean and standard deviations were calculated. ANOVA was performed to determine significant differences in mean values. All the statistical tests were applied using R software (ver. 3.5.3).

3. Results and Discussion

Trace elements in *Solanum nigrum* L. exhibited a clear seasonal fluctuation in all plant parts. Maximum Cobalt (Co) contents were noted in all plant parts during winter. Co content in berries was measured at maximum of 49.67 ± 5.51 mg/kg of dry weight during winter which lowered to 27.67 ±5.86 during summer season. Least Co contents were measured in Mako root during summer season. Maximum Manganese (Mn) contents were noted in berries (63.33±7.64 mg/kg of dry weight) during winter. Least Mn contents were measured in leaves during summer season. *Solanum nigrum* L. is an hyperaccumulator of (Cadmium) Cd (Wei et al., 2005). It was reported in literature that Mn uptake is affected by Cd as it interacts with Mn. Copper acquisition and transport in plants is not a well understood phenomenon (Williams et al., 2000; Yruela, 2009). Copper (Cu) contents were also found maximum during winter season. Highest quantities of Cu (174.5 ±10.5 mg/kg) were found in leaves during winter. Statistically significant (p <0.005) differences were found in plant parts during winter. However, ~ 104 mg/kg of dry weight Cu content were found during summer regardless of plant part. Since, summer is actively growing season for plant so we can assume a dilution effect in Co, Cu and Mn contents noted during summer season in all plant parts as compared to what noted during winter season.

Iron (Fe) content in both root and leaves during winter season was found at an average of ~2300 mg/kg of dry weight. However, 550.67±22.48 mg/kg was found in berries. During summer season, an average of 850 mg/kg of dry weight Fe content was found in leaves and berries as compared to 1248.33±2.89 mg/kg in root. Results are contradictory to what was reported in literature that lower uptake and transport of Fe is found in high alkaline soil (Curie and Briat, 2003; Kim and Guerinot, 2007). High pH (7.4-8.5) interferes with iron solubility and uptake by the plants unless intervened by other modifying factors such as Fe-interactions with Zn, Cu, Mn, N and P of soil. A researcher, which may be the reason for higher

Fe content in plant roots during winter (pH 7.81) (Lindsay, 1984).

Table 3: Mean squares for Co, Cu, Fe, Mn, Zn concentration in different plant parts during different seasons

Source of variance	Df	Co	Cu	Fe	Mn	Zn
Plant parts	2	421.1 ***	180.55***	2027005 ***	2766.0***	132.0 ***
Seasons	1	1762.2 ***	9362***	2477167 ***	610.2***	251.6***
Seasons * Plant Parts	2	6.1	701**	1249710 ***	146.4***	320.8***
Error	12	11.5	61	9736	10.2	0.3

Significant codes: '***' 0.001 '**' 0.01 '*' 0.05, ns=nonsignificant

Zinc (Zn) contents were found maximum in berries and leaves during summer whereas, maximum Zn contents i.e. 18±1 mg/kg of dry weight of root were measured in roots during winter season. Environmental factors such as arid soil and high temperature favors uptake of zinc from soil while high pH (pH > 6.5) limits the availability of the same element (Hafeez et al., 2013). Thus, plant parts collected from this soil was deficient of Zn trace element. More alkaline soil during winter (7.81 pH) might have resulted in less transport of Zn in berries and leaves of Mako. During summer season Zn accumulation in root (12.28±0.072 mg/kg) was lower than that noted during winter season (18±1 mg/kg). However, more accumulation of Zn in berries and leaves during summer may be attributed to the fact that summer is the active season for this plant in Soone Valley (Hafeez et al., 2013). Although Mako is an annual herb but it was frequently observed to attain perennial habitat in Soone Valley perhaps due to prevalent environmental conditions, that is why, berries were also collected during summer season (Defelice, 2003; Peng et al., 2008). Least Zn content (1.47±0.45 mg/kg) were noted for berries during winter season which was supposed to be the actual season for fruiting for this plant.

4. Conclusion

It is concluded that role of trace elements in herbal formulations is crucial. Our research regarding trace elements in *Solanum nigrum* L. supported the utilization of this plant to combat ailments specifically certain nutritional deficiency related disorders. However, seasonal variations play significant role in altering its elemental composition. Thus, it is recommended to carry out further research before utilizing this plant in herbal formulations reported in literature.

Novelty Statement

Trace elements are crucial to maintain normal health of living organisms. Plants uptake these elements from soil and are substantial if not the only source of these nutrients in human diet. *Solanum nigrum* L. is used as vegetable in many parts of the world and based on its nutritional status it can be used as a source of essential trace elements. However, environmental variations may alter nutritional status of aforementioned plant, hence, it is important to study effect of seasonal variations in this regard.

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