

Full Length Research Paper

Accumulative capabilities of essential nutrient elements in organs of *Monsonia burkeana*

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***Monsonia burkeana* is widely used as herbal tea in South Africa. However, the accumulative capabilities (ACs) of its organs for essential nutrient elements are not documented. A study was conducted to determine the ACs for nutrient elements in fruit, leaf, stem and root of *M. burkeana*. Ten plants per plot, with three replicates, were harvested whole, oven-dried separately into the four organs and quantified for selected essential nutrient elements. On average, the increasing order of macronutrients in various organs was as follows; fruit = Ca > N > K > P > Mg, leaf = Ca > N > K > P ≥ Mg, stem = K > Ca > N > P ≥ Mg and root = K > N > Ca > P ≥ Mg. In contrast, for micronutrients the order was as follows; fruit = Cl > Fe > Mn > Cu > Zn > B, leaf = Cl > Cu > Fe > Zn > Mn > B, stem = Cl > Cu > Fe > Mn > Zn > B and root = Fe > Cl > Cu > Mn > Zn > B. In conclusion, the ACs for essential nutrient elements differed, with the reproductive and vegetative organs having high ACs for macro-nutrients, whereas, roots had high ACs for micro-nutrients. Herbal tea from *M. burkeana* leaves has the potential to provide the dietary essential nutrient element requirements.**

Key words: Accumulative capability, *Monsonia burkeana*, essential nutrient elements, traditional medicine.

INTRODUCTION

The trade network of *Monsonia burkeana* in South Africa constitutes part of a multi-million dollar 'second economy'. Decoctions from *M. burkeana*, locally referred to as 'special tea', are used; (1) in parts that are concocted with herbs such as Bonsai-crassula (*Crassula sarcocaulis*) and foxgloves (*Digitalis purpurea*) to cure various sexually transmitted diseases; (2) to cleans blood (IKS); (3) to improve erectile dysfunction; (4) to enhance libido on male subjects (WO, 2007). The trade of 'special tea' at roadside markets includes: (1) Sale of decocted material in plastic bottles of various sizes and (2) tied bundles of plant dried materials.

Despite the widespread use of decoctions from this plant by most of the marginal communities in South Africa, information on its nutrient composition is scanty.

The content of essential nutrient elements in a given organ depends on the organ's accumulative capabilities (ACs) and the interactions of the nutrient elements in that organ (Salisbury and Ross, 1992). Information on the ACs of organs is important since in addition to providing the nutrition value of an organ, it also provides information which assist in selective harvesting of organs instead of harvesting the whole plant. The objective of this study was to determine the ACs of fruits, leaves, stems and roots using selected essential nutrient elements in order to establish whether the plant should be harvested in whole or in part.

MATERIALS AND METHODS

Study location and experimental design

Fresh plant materials were sampled in 2008 and 2009 from Chuenespoort, Limpopo Province, South Africa (24°21'4" S,

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Table 1. Accumulative capabilities of nitrogen, phosphorus, potassium, calcium and magnesium in the fruit, leaf, stem and root of *M. burkeana*.

Organ	Macro nutrients (%)				
	N	P	K	Ca	Mg
Fruit	1.35 ^a	0.32 ^b	1.41 ^c	1.79 ^b	0.27 ^a
Leaf	1.40 ^a	0.28 ^b	1.25 ^c	2.68 ^a	0.27 ^a
Stem	0.84 ^b	0.41 ^a	2.51 ^a	1.75 ^b	0.25 ^a
Root	0.73 ^c	0.26 ^b	1.91 ^b	0.74 ^c	0.25 ^a
SE	0.02	0.02	0.13	0.07	0.01

Column means with the same letter were not different ($P \leq 0.05$) according to the Tukey' honest significant different test.

29°48'4" E) during fruiting. Plots of 10 × 10 m were arranged in a randomised complete block design with three replicates, where blocking was done for slope. Ten plants within each plot were randomly sampled by collecting the entire plant and transported in cooler boxes to the Horticultural Skills Centre of the University of Limpopo, Turfloop Campus (23°53'10" S, 29°44'15" E).

Essential nutrient element determination

Whole plants were dried in air-forced ovens at 52°C for 48 h (Makkar, 1999). Fruit, leaves, stems and roots were individually ground in a Wiley mill to pass through a 1 mm sieve and stored in air-tight plastic containers at 5°C prior to analysis. Ground samples were prepared for data collection using the modified method recommended by Association of Official Analytical Chemists (1984). Briefly, the method entailed taking 2 g plant material per organ and ashing in porcelain crucibles at 550°C in a muffle furnace for 24 h. The ash was then dissolved in 5 ml of HNO₃/HCl/H₂O (1:2:3 v/v/v) and heated gently on a hot plate until brown fumes disappeared. Five-ml de-ionized water was added to the remaining content in each crucible and the mixture was heated until a colourless solution was obtained. The solution in each crucible was transferred into a 100 ml volumetric flask, filled up to the mark with de-ionized water and filtered using Whatmann no. 42. Copper, Ca, K, Mg, Mn, Zn and Fe were quantified using Perkin Elmer Atomic Absorption Spectrophotometer; whereas, Auto Analyser 3 (AA3) segmented flow was used to determine P (Association of Official Analytical Chemists, 1984). Boron was quantified through colorimetry using azomethine-H (Gaines and Mitchell, 1979) and Cl with chlorometer. One gram of ash sample for N was shaken in 40 ml of a 10% trichloroacetic acid (TCA) solution at 20°C for 1 h using a wrist-action shaker. The insoluble residue was removed by centrifugation at 5000 rpm for 10 min, with residues treated three times with 15 ml of a 10% (w/v) TCA solution. The supernatant was collected, its volume made up to 100 ml with distilled water with the aliquot taken for the determination of soluble N using the Kjeldahl procedure (Association of Official Analytical Chemists, 1984).

Data analysis

Prior to analysis, data for micro nutrients were transformed using $\log_{10}(x+1)$ in order to homogenise the variance (Gomez and Gomez, 1984). However, untransformed data were reported. Data were subjected to analysis of variance (ANOVA) using Statistix software in linear model procedure. The Tukey's honestly significant

difference (HSD) test was used to identify differences among the means at the probability level of 5%. Unless otherwise stated, means for essential nutrient elements were different at the probability level of 5%.

RESULTS

Macro-nutrients

The four test organs had different ACs for macro-nutrient elements N, P, K and Ca (Table 1). The fruit and the leaf had the highest ACs for N, with those of the stem and the root being moderate and low, respectively. The stem had the highest ACs for P, whereas those in the other three organs were not different. The stem had the highest ACs for K, followed by the root and then, the fruit and the leaf. The leaf had the highest ACs for Ca, with those of the fruit and the stem being moderate, whereas, those in the root were the lowest. All four test organs had similar ACs for Mg. On average, the increasing order of macronutrients in the tested organs was as follows; fruit = Ca > K > N > P > Mg, leaf = Ca > N > K > P ≥ Mg, stem = K > Ca > N > P ≥ Mg and root = K > Ca > N > P ≥ Mg.

Micro-nutrients

The four test organs had different ACs for the six micro-nutrients measured (Table 2). The ACs for Cu in the leaf, the stem and the root were not different, whereas those in the fruit were lower than those in the leaf, but were not different to those in the stem and the root. The ACs for Fe was the highest in the leaf and the root and the lowest in the fruit and the stem. The leaf and the root had the highest ACs for Zn, with the fruit and the stem having the lowest. The root had the highest ACs for Mn followed by the leaf, whereas the fruit and the stem had the lowest. The leaf had the highest ACs for B, whereas the fruit and the stem had moderate ACs for B and the root had the

Table 2. Accumulative capabilities of copper, iron, zinc, manganese, boron and chlorine in the fruit, leaf, stem and root of *M. burkeana*.

Organ	Micro-nutrients (ppm)					
	Cu	Fe	Zn	Mn	B	Cl
Fruit	81.5 ^b	137.00 ^b	47.33 ^c	93.67 ^c	26.50 ^b	2 600 ^a
Leaf	795.0 ^a	336.00 ^a	231.00 ^a	153.00 ^b	28.33 ^a	1 400 ^c
Stem	148.3 ^{ab}	117.33 ^b	76.33 ^b	94.00 ^c	22.33 ^b	1 900 ^{ab}
Root	373.3 ^{ab}	415.33 ^a	182.00 ^{ab}	191.00 ^a	20.00 ^c	400 ^d
SE	193.20	17.89	43.00	3.56	1.05	0.01

Column means with the same letter were not different ($P \leq 0.05$) according to the Tukey' honest significant different test.

lowest. The fruit and the stem had the highest ACs for Cl, with the leaf having moderate ACs for Cl, whereas the root had the lowest. On average, the increasing order of micronutrients was as follows; fruit = Cl > Fe > Mn > Cu > Zn > B, leaf = Cl > Cu > Fe > Zn > Mn > B, stem = Cl > Cu > Fe > Mn > Zn > B and root = Fe > Cl > Cu > Mn > Zn > B.

DISCUSSION

The differences in the partitioning of the quantified macro- and micro-elements within various organs of *M. burkeana* may be attributed primarily to the ACs of individual organs. Factors such as the preferential absorbability of a particular organ for the corresponding element, the age of the plant, the mineral composition of the soil in which the plant grows and the ambient climatological conditions all have a role in accumulation of different quantities of essential nutrient elements in different plant organs (Serfor-Armah et al., 2001). Different ACs for essential nutrient elements in different organs of *M. burkeana* confirmed those observed in barley (*Hordeum vulgare*), flax (*Linum usitatissimum*), seagrass (*Posidonia australis*; *Posidonia sinuosa*) and annual lupins (*Lupinus* species) (Bowen, 1976; Epstein, 1972; Hocking and Pate, 1978; Hocking et al., 1980; Moraghan, 1993).

Accumulation capability for macronutrient elements

Generally, *M. burkeana* conspicuously accumulated the highest concentration of macro-elements in reproductive and vegetative organs, whereas the roots accumulated appreciable concentrations of micro-elements. The lower concentrations of the macro-nutrient elements in the roots are indicative of high rates of their transportation to shoots (Baldantoni et al., 2009), resulting in high ACs for macronutrients in reproductive and vegetative organs of

M. burkeana. The high level of macronutrients in aerial organs, particularly in the leaves, agreed with the ACs of leaves in *Phragmites australis* (Baldantoni et al., 2009).

The high ACs of the leaves for Ca could be explained in relation to the role of this element in plants. Calcium is the constituent of calcium pectate in the middle lamella, which binds adjacent cell walls together (Campbell, 1990). Apart from this structural function, Ca promotes ACs for K and also prevents K from leaching out of organs as senescence sets in (Epstein, 1961). Calcium ions also serve a protective function. For instance, it protects organs from the injurious effect of H⁺ ions, high salinity ions and other toxic ions (Epstein, 1961). The addition of Ca into an organ substantially reduces protein loss and maintains active accumulation of ions required by plant organs (Bonner, 1976). Additionally, Ca enhances the ACs for B (Wildes and Neales, 1971), which may provide some explanation to the higher content of B in leaves than in roots.

In view of the listed facts, high levels of essential nutrient elements in shoots, particularly in the leaves, were due to the ability of Ca to enhance the ACs for other minerals such as B and K as well as its protective role. Low Ca in the roots of *M. burkeana* failed to enhance the ACs for other essential nutrient elements and therefore, their low concentrations. The cell wall-binding capability of Ca translates to minimum leaching out of essential nutrient elements in above ground organs of *M. burkeana*.

Generally, concentrations of sucrose in an organ are inversely proportional to those of osmoticum ions (K, Na, Cl) as a measure of balancing the turgor pressure (Bonner, 1976; Mashela and Nthangeni, 2002). Translocation of sucrose is closely linked to the concentration of K (Hartt, 1970); with circulation of K around the sieve plates of the phloem being part of the mechanism that increases translocation of sucrose in sieve tubes (Spanner, 1958). Consequently, a decrease in K content incidentally reduces translocation of sucrose by depressing the electro-osmotic potential gradient across the sieve plates. Any factor that decreases

transportation of K alters the electro-osmotic potential between sieve tubes, thereby, reducing sucrose translocation. Also, K is essential for the synthesis of starch (Campbell, 1990). In view of these facts, accumulation of leaf K in *M. burkeana* may translate to accumulation of proximate compounds such as carbohydrates, proteins, fats and vitamins. *M. angustifolia* leaves have vitamin C, protein and fat ranging from 249.6 to 266 mg/100 g material, 0.6 to 5.0% and 0.1 to 1.0%, respectively (Lyimo et al., 2003).

Normal levels of macronutrient elements in plants are defined as 0.11 to 0.17% for P (Smidt, 1988), 0.35 to 0.66% for K (Zöttl and Hüttl, 1989), 0.23 to 0.50% for Ca and 0.05 to 0.13% for Mg (Smidt, 1988). Relative to the listed nutrient element levels, results from the current study suggested that *M. burkeana* has a much better ACs for essential nutrient elements and therefore, may serve as a good source for those elements.

Accumulation capability for micro-nutrients

Among the evaluated micro-elements, the concentration of Cl was consistently the highest in all organs, except in the roots where it was second highest. Boron was the lowest in all organs. Except under conditions where extrinsic stresses force more sucrose to be channelled towards roots, as an osmoticum ion, the Cl ion is mobilised to leaves (Mashela and Nthangeni, 2002), where toxic concentrations are avoided through leaf abscission.

Relative to other micronutrients, the roots exhibited the highest concentration of Fe. The chemical properties of Fe are responsible for its role in oxidation-reduction reactions and since Fe is a transitional metal, it is capable of existing in more than one oxidation state (Bonner, 1976). Iron forms stable chelates with molecules containing oxygen, sulfur or nitrogen and also accumulates in nuclei of root cells (Possingham and Brown, 1957). This may be the reason Fe was the highest in roots. The same applies to Mn. The high levels of Fe and Mn in the roots might also have been as a result of low rates of transportation to the shoots.

Generally, the ranges of micro-nutrients in crops are between 4 and 15 ppm for Cu and 15 to 200 ppm for Zn (Allaway, 1986; Bowen, 1966). Relative to the cited ranges, the 795 ppm for Cu and 231 ppm for Zn in the leaves of *M. burkeana* were remarkable.

Health attributes of *M. burkeana*

Leaves of *M. burkeana* could be a good source of N, Ca, Mg, Cl, Cu, Fe, Zn, Mn and B, since these elements were much higher than those of green tea and other health

beverages (Abolaji et al., 2007; Almeida et al., 2007). Healthcare literature is replete with empirical evidence which suggest that, plants with high concentrations of macro- and micro-nutrient elements play important roles in maintenance of human health. Generally, most nutrient elements play important roles in the formation of active metabolites in medicinal plants (Serfor-Armah et al., 2001). Also, essential nutrient elements have various curative roles. For instance, Ca is a major essential nutrient element in bones and teeth, but it is also involved in normal muscle contraction and relaxation, blood clotting, proper nerve functioning and improvement in the body immune defence system (Hamilton et al., 1988). Magnesium plays an important role in the formation and functions of bones and muscles, but may also prevent various disorders such as high blood pressure, depression, irritability, nervousness, dizziness, muscle weakness, twitching and spasms and certain heart diseases (Smith and Hammarsten, 1958). Magnesium is also critical to energy production and is important in cardiovascular health as it helps with the relaxation of arteries.

M. burkeana is traditionally harvested whole for its capacity to cleanse blood which is probably also related to improving erectile dysfunction. Along with concoctions from other plant species, it is used in curing certain sexual transmitted diseases. With nutrients always having multiple and diverse functions, Ca is one of the important essential nutrient elements that are known to have potency-enhancing capabilities. Together with B, Mg, Cu, Zn and Fe, Ca had been reported to increase the level of testosterone, whereas Mn is known to reduce this male sex hormone (Nielsen et al., 1987).

Conclusions

In terms of nutrient element results, this study suggested that the leaves, the stems and the fruits of *M. burkeana* have good ACs when compared with the roots. However, the leaves have potential to serve as the harvestable material for commercial packaging. Also, this herb has the potential to serve as an important source of essential nutrient elements in marginal communities of South Africa, where it is widely consumed as 'special tea' with already established trade networks.

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