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Some Canadian-Grown Potato Cultivars Contribute to a Substantial Content of Essential Dietary Minerals

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ABSTRACT: Potato consumption provides significant dietary contributions to several essential minerals, but the effects of cultivar and planting site are not well-understood. The mineral content of 16 cultivars, grown at 5 locations, was measured using inductively coupled plasma−optical emission spectroscopy and evaluated on a per serving basis for percent recommended daily intake (% RDI), emphasizing some minerals where global deficiencies are common (calcium, iron, selenium, and zinc). Discriminant analysis showed that both genotype and growing location were important. Differences in mineral content occurred between cultivars at each site, specific cultivars at different sites, and collectively between sites. 'Freedom', 'Yukon Gold', and particularly the very stable mineral source 'Russet Burbank' contributed most to the % RDI for minerals. One serving per day of these cultivars provides a significant contribution to the % RDI for the macrominerals magnesium, phosphorus, and potassium and the trace minerals copper, iron, selenium, and zinc.

KEYWORDS: *canonical discriminant analysis, ICP−OES, % RDI, Solanum tuberosum L.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important food staple for humans in both developed and developing countries, with 6.5, 15.9, 45.0, 32.0, and 0.7% of world production consumed in Africa, America, Asia, Europe, and Oceania, respectively, in 2007.[1] Although the potato is an increasingly important dietary staple worldwide, its nutritional attributes are sometimes superseded by perceived concerns that the high starch content of potatoes contributes to an unhealthy Western dietary pattern.[2] Minerals play a crucial role in health maintenance by functioning as electrolytes, enzyme constituents, and structural components for bones and teeth.[3] The trace minerals copper (Cu), iron (Fe), manganese (Mn), selenium (Se), and zinc (Zn) are integral constituents in the antioxidant defense system in the form of metalloproteins.[4] Antioxidants neutralize free radicals and prevent oxidative tissue damage, which is linked to the initiation and progression of a wide range of chronic diseases, including cardiovascular diseases, cancer, diabetes, and neurodegenerative diseases. Mineral deficiencies are prevalent in both developed and developing countries because of the relatively low content of bioavailable minerals in many staple crops. Globally, calcium (Ca), Fe, Se, iodine (I), and Zn deficiencies are the most widespread forms of mineral malnutrition. Billions of people are affected by mineral deficiencies that increase childhood disabilities, mortality, and elevate health care costs.[5] Over 1.5 billion people worldwide are anemic, primarily because of Fe deficiency, while 3.7 billion persons are deficient in Fe.[4,6,7] Fe, I, and Zn deficiencies contribute to daily losses of 65.6 million dollars or about 4.5% of the global burden of nutritional risks.[8] Dependent upon the age range and gender, many Canadians do not appear to be meeting their dietary needs for Ca,[9] magnesium (Mg),[10] phosphorus (P),[10] Zn,[10] Cu,[11] and Fe.[12]

Potato, as a major staple food crop, could play an important role to combat mineral deficiencies, in part because of its relatively high content of certain macro- and trace minerals.[13,14] Importantly, potato tubers also contain a relatively low content of antinutrients that decrease mineral bioavailability, such as oxalates[7,15] and phytates.[7,16] Moreover, compounds that promote mineral bioavailability, such as ascorbate, β-carotene, organic acids, and cysteine-rich polypeptides, are found in relatively high concentrations in potatoes.[17]

Because of the high intake of potatoes in many countries worldwide, small differences in potato mineral composition could have a major impact on population health, particularly with respect to common mineral deficiencies. There are, however, contradictory reports regarding which major and trace essential minerals are found in nutritionally important concentrations in potatoes. Published studies of mineral content in potato are summarized in Tables 1 and 2, in which mineral content is expressed on a per serving basis of 148 g of fresh mass (FM). These tables illustrate the tremendous variation among research studies regarding the essential mineral content provided by one serving of potato. Significant contributions of Fe and Zn to the diet were reported for 74 Andean genotypes.[18] Potato has been reported to be a "good source" of the major minerals Ca, Mg, P, and potassium (K) and the trace minerals Fe and Zn.[13,14] On the other hand,

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Table 1. List of Reported (or Estimated[a]) Macromineral (Ca, K, Mg, Na, and P) Values from Published Studies Expressed as Milligrams in One Serving (148 g of FM)

reference	cultivars and genotypes	Ca	K	Mg	Na	P
3	average of 5 unidentified cultivars from the Andigenum group	9.47	618.64		4.74	74.00
14	Centennial Russet, Katahdin, Kennebec, Norchip, Norgold, Pontiac, Russet Burbank, Superior, White Rose	9.80	846.00	31.29	11.56	71.84
15	Idaho potato	15.77	618.72	35.66		74.19
	non-Idaho potato	10.58	629.28	34.51		76.52
18	74 native Andean genotypes	40.12−161.75				
35	Chippewa, Green Mountain, Irish Cobbler, Katahdin, and Rural	7.40−11.48	621.60−799.20	19.24−103.60	29.60−74.00	44.40−162.80
21	Arran Banner, Cara, Spunta, Up-to-Date	20.72−26.64	710.40−885.04	26.94−31.97	11.54−18.35	85.84−109.52
24	Agata, Agria, Chieti, Emilia Romagna, Lazio, Molise, Pescara, Puglia, Teramo, Sirco, Veneto			312.71−361.82		
	Russet Burbank					
26	East; New Brunswick	2.37	503.20	28.12	69.56	62.16
	West; Alberta and Manitoba	4.00	518.00	35.52	68.08	57.72
19	Russet Burbank	8.33	616.05	29.304		63.27
36	Katahdin	12.80	658.00	32.80	1.33	102.20
37	Russet Burbank	2.78	131.13	6.45	4.91	
38	Arinda, Rossa di Cetica, and Sieglinde	129.83	578.09	31.97	0.17	81.40
39	Ditta	37.00	666.00	33.30		66.60
40	Superior (organic and conventional)	4.24	435.12	24.47	1.09	51.11
		4.64	395.65	22.30	0.59	40.75
range		0.89−161.75	82.88−885.04	4.44−361.82	0.17−74.00	40.75−162.80

[a]Estimate based on reported % DM or when non-reported 20% DM used for conversion (overall average from published reports).

Table 2. Range of Trace Mineral (Cr, Cu, Fe, Mn, Mo, and Zn) Content in mg 148 g^{-1} FM of Potato Cultivars Reported in Previous Studies

reference	Cr	Cu	Fe	Mn	Mo	Zn
3			0.64			
13		0.29	1.11	0.38	0.14	0.61
14	0.011	0.13	1.03	0.20	0.011	0.37
	0.022	0.17	1.20	0.31	0.014	0.53
18			0.88−4.59			1.86−4.27
35		0.15	1.33	0.89		0.59
21			2.19−3.91	0.27−0.38		0.38−0.50
24	0.02−0.04	2.59−2.73	5.80−6.67	1.65−2.01		3.67−3.76
26		0.27	0.81	0.41		0.52
		0.16	0.64	0.21		0.37
19		0.11	2.16	0.43		0.33
36	0.032	0.29	1.82	0.32		0.62
37		0.03	0.11	0.04		0.06
38	0.002	0.21	0.56	0.21		0.53
39	0.007	0.16	1.63	0.27		0.60
40		0.12	0.64	0.13		0.33
		0.13	0.62	0.15		0.27
range	0.002−0.04	0.11−2.73	0.08−6.67	0.13−2.01	0.011−0.038	0.06−3.76

potato was described as a "major supplier" of Cu, Mg, P, Fe, I, and Zn but not Ca based on the recommended daily intake (RDI).[13] The RDI forms the basis for the determination of the daily value (DV) used in nutrition fact labels for describing the nutrient contribution of food servings toward meeting the recommended nutrient intakes in Canada and the U.S.A.

Potato mineral content is affected by a long list of parameters, including genotype (affecting metabolic requirements), soil type and composition, weather (including rainfall and temperature patterns), and cultural practices, such as irrigation and fertilization regimes and harvest dates.[3,13,19,20] The planting site is largely affected by many of the latter factors and plays a major role in determining potato mineral content. Most multicultivar, multisite studies have found variability in tuber levels for only specific minerals and cultivars. For example, only two minerals (Fe and Zn) but not seven others [Ca, Cu, K, Mg, Mn, P, and sodium (Na)] measured in four cultivars were affected by growing sites in Cyprus.[21] Additionally, five minerals (Ca, K, Na, P, and Se) varied in three cultivars (including Russet Burbank) but not in six other cultivars at different growing sites in the U.S.A.[13]

Environment and genotype × environment interactions are also important, and such interactions were found to significantly affect mineral content in 37 of 49 native Andean

Table 3. Dry Matter (%) and Least Squares (LS) Mean Values for Macrominerals (Ca, K, Mg, Na, and P) in One Serving (mg/148 g FM) of Potato Cultivars Grown at Different Canadian Sites: Taber [Alberta (AB)], Bon Accord [New Brunswick (BA)], Florenceville [New Brunswick (FL)], Carman [Manitoba (MB)], and St-Ubalde [Quebec (QC)][a]

cultivar	site	*N*	dry matter (%)	Ca	K	Mg	Na	P
Atlantic	BA	5	20.87	3.87^{i3}	293.03^{e3}	14.11^{g3}	0.51^{d2}	47.26^{g3}
Green Mountain	BA	5	20.64	53.45^{abc1}	1685.19^{cd2}	109.24^{ef2}	8.12^{b1}	348.95^{a-f12}
Goldrush	BA	5	19.55	4.97^{i3}	260.48^{e3}	14.79^{g3}	1.00^{cd2}	48.47^{g3}
Kennebec	BA	5	20.24	3.34^{i3}	234.24^{e3}	15.24^{g3}	0.31^{d2}	50.44^{g3}
Norland	BA	5	21.71	21.28^{h2}	2052.78^{abc1}	153.34^{a-d1}	2.90^{bcd2}	411.44^{ab1}
Onaway	BA	5	19.85	3.16^{i3}	223.58^{e3}	14.92^{g3}	0.59^{d2}	42.23^{g3}
Russet Burbank	BA	5	19.51	44.95^{bcd1}	1897.45^{bcd12}	126.96^{c-f12}	3.81^{bcd12}	335.59^{a-f12}
Red Pontiac	BA	5	17.85	4.36^{i3}	239.83^{e3}	12.60^{g3}	1.04^{cd2}	42.88^{g3}
Sebago	BA	5	19.18	22.61^{gh2}	1834.12^{bcd12}	107.98^{ef2}	3.90^{bcd12}	262.93^{def2}
Shepody	BA	5	18.28	25.63^{fgh2}	1987.10^{abc12}	146.61^{a-f1}	1.92^{cd2}	390.40^{ab1}
Superior	BA	5	19.23	3.99^{i3}	227.35^{e3}	14.44^{g3}	0.38^{d2}	44.87^{g3}
Yukon Gold	BA	5	16.78	27.81^{e-h2}	1875.01^{bcd12}	127.23^{c-f12}	3.21^{bcd2}	256.42^{ef2}
mean				19.97^{3}	1095.37^{3}	73.23^{5}	2.39^{3}	198.68^{4}
Innovator	AB	10	22.84	41.95^{cde1}	1985.22^{abc2}	155.22^{a-d1}	13.61^{a2}	331.10^{b-f2}
Russet Burbank	AB	10	25.14	37.67^{def1}	2224.54^{abc1}	161.39^{abc1}	18.93^{a1}	381.20^{abc1}
mean				39.81^{1}	2104.88^{1}	158.30^{1}	16.27^{1}	356.15^{1}
Freedom	MB	10	22.74	58.63^{ab1}	2173.12^{abc12}	170.81^{ab12}	4.95^{bcd1}	346.41^{a-f1}
Highland Russet	MB	10	23.34	55.10^{abc1}	2525.02^{a1}	185.12^{a1}	3.66^{bcd1}	371.15^{a-d1}
Innovator	MB	10	23.44	4.93^{i3}	282.972^{e3}	14.96^{g3}	0.74^{d2}	63.79^{g2}
Russet Burbank	MB	10	22.48	43.03^{cd2}	2046.29^{abc2}	140.70^{b-f2}	5.59^{bcd1}	301.54^{b-f1}
mean				40.42^{1}	1756.85^{2}	127.90^{3}	3.73^{23}	270.72^{3}
Freedom	FL	10	25.42	36.37^{d-g1}	1844.51^{bcd1}	123.96^{c-f23}	3.22^{bcd1}	351.78^{a-f1}
Highland Russet	FL	10	22.87	3.79^{i2}	275.84^{e2}	15.64^{g4}	0.47^{d2}	51.99^{g2}
Innovator	FL	10	22.66	35.78^{d-h1}	1949.84^{abc1}	155.03^{a-d1}	2.39^{cd12}	366.03^{a-e1}
Russet Burbank	FL	10	23.38	35.00^{d-h1}	2061.37^{abc1}	148.69^{a-d12}	2.41^{cd12}	370.55^{a-e1}
Victoria	FL	10		33.24^{d-h1}	1801.93^{bcd1}	118.65^{def3}	4.02^{bcd1}	303.79^{b-f1}
mean				28.84^{2}	1586.70^{2}	112.39^{4}	2.50^{3}	288.83^{23}
Chieftain	QC	5	18.16	30.36^{d-h3}	1348.58^{d2}	105.18^{f2}	4.62^{bcd1}	246.40^{f}
Goldrush	QC	5	19.57	61.83^{a1}	2342.72^{ab1}	178.25^{ab1}	4.59^{bcd1}	449.17^{a13}
Russet Burbank	QC	5	21.70	44.27^{bcd2}	1683.95^{cd2}	113.99^{def2}	4.39^{bcd1}	268.74^{c-f3}
Yukon Gold	QC	5	18.66	31.38^{d-h23}	2496.47^{a1}	171.11^{ab1}	6.29^{bc1}	330.68^{b-f2}
mean				41.96^{1}	1967.93^{1}	142.13^{3}	4.97^{2}	323.75^{12}
overall mean				30.90	1557.18	110.86	4.41	266.60

[a]Means were compared using Tukey's honest significant difference test ($p \leq 0.05$); $n = 5-10$ replicates. Means with the same superscript letter or number are not significantly different. Superscript letters label differences between cultivars from different growing sites, and superscript numbers designate differences between cultivars from the same growing site. Differences between overall means of each growing site were illustrated by superscript numbers. For example, to examine differences among cultivars from field sites, superscript letters are compared. To investigate differences among cultivars at the same growing site, superscript numbers are compared.

potato varieties.[22] Likewise, there was a significant effect of genotype × environment in the Fe content of 13 genotypes, including 'Russet Burbank', of 33 genotypes tested.[23] In a study conducted with four potato cultivars and three sites, there was a significant effect of the planting site on Ca, K, and P contents, while within each location, there were no differences between genotypes, except 'Lena' for P content.[20] The impact of the planting site on the mineral content was shown by Anderson et al., who were able to precisely distinguish market or farm samples of Idaho from non-Idaho potatoes based on mineral analysis using inductively coupled plasma–atomic emission spectroscopy and statistical analysis using discriminant function analysis and neural network classification.[14] Similarly, discriminant analysis has been used to determine geographic origin; cultivars grown in the Fucino basin were distinguished on the basis of the pattern of 10 trace minerals compared to those grown in Abruzzo and other Italian regions.[24]

The objective of the current study was to measure the mineral content of 16 potato cultivars grown at different sites in Canada to determine (1) their relative mineral contribution as a percentage of the recommended daily intake (% RDI), particularly for minerals for which global and Canadian deficiencies are common (the macrominerals Ca, Mg, and P and the trace minerals Cu, Fe, Se, and Zn), and (2) whether cultivars and growing site could be discriminated for nutritional purposes based on the mineral content.

MATERIALS AND METHODS

Potato Tuber Sampling and Digestion. The potato cultivars, growing sites (closest city), and suppliers are listed in Table 3. As tubers were received from the suppliers, they were stored in a growth chamber [10–13 °C, approximately 85% relative humidity (RH)] for up to 2 weeks prior to analysis. Potato tubers ($n = 5-10$; Table 3) were rinsed, blotted onto paper towels, and air-dried for 1–2 h. Samples consisted of 1 g of homogenized tissue from a cross-sectional slice (~1 cm thick) taken from the middle of a whole tuber. Homogenates were incubated overnight in 10 mL Oak Ridge centrifuge tubes (Thermo Scientific, Rochester, NY) containing 3.0 mL of nitric acid (trace metal analysis grade; Fisher Scientific Co.,

Nepean, Ontario, Canada) in a chemical exhaust hood. Digestion was completed (6−8 h at 105 °C) on a heating block (Dri-bath model DB16525, Thermolyne, Dubuque, IA) until evolution of nitrous oxide gases (brown gases) stopped.

Mineral Analysis via ICP−OES. Mineral analysis was performed using ICP−OES (model VISTA-MPX CCD, Varian Australia Pty Ltd., Australia). The settings were as follows: power, 1.2 kW; plasma flow, 15 L min^{-1}; argon pressure, 32 L min^{-1} (600 kPa); nebulizer flow, 0.75 L min^{-1}; auxiliary flow, 1.5 L min^{-1}; pump rate, 15 rpm; viewing height, 10 mm; replicate reading time, 10 s; and instrument stabilization delay, 15 s. Control elemental stock standard solution (J.T. Baker, St. Louis, MO) was used to calibrate the instrument. Digests were diluted (1:4) with type-1 water (18 Ω cm) and mixed thoroughly prior to injection into ICP−OES for analysis. Results of mineral contents of potato cultivars were calculated as milligrams per one serving of potato (148 g of FM). For estimation of % RDI values, the concentrations of minerals in one serving of potato were divided by the RDI values[3,25] and multiplied by 100.

Statistical Analysis. The experiment was arranged as a factorial design with two main factors: cultivar and growing site. A total of 5−10 tubers per cultivar represented 5−10 replicates, with 1 tuber as an experimental unit. Mineral results were subjected to Proc GLM, SAS, version 9.2 (SAS Institute, Inc., Cary, NC). Significant means were compared using Tukey's honest significant difference post-hoc test ($p \leq 0.05$). Pearson correlation coefficients of mineral elements were tested using Proc CORR of SAS (SAS Institute, Inc., Cary, NC).

The mineral results of Ca, Cu, Fe, K, Mg, Na, P, Se, and Zn that showed significant variation among treatments (cultivars) were subject to canonical discriminant analysis (CDA) and hierarchical cluster analysis (HCA) to be classified across locations using the CANDISC procedure of SAS. The canonical (CAN) scores from the analysis were used for HCA, for further unsupervised classification of cultivars within locations. The Euclidean distance between group's centers in canonical space was used to construct a similarity measure matrix to better visualize the clustering pattern of groups of cultivar, site, and replicate combinations.

RESULTS AND DISCUSSION

Differences among Cultivars at All Sites. Significant differences were found in the mineral content of tuber tissues between cultivars at the five sites (Tables 3 and 4). Macrominerals (mg/serving) varied widely between potato cultivars: 20-fold (Ca, 3.16−61.83), 60-fold (Na, 0.31−18.93), and >100-fold (K, 227.35−2525.02; Mg, 12.60−185.12; and P, 42.88−449.17) (Table 4). These results are in the range of reported tissue levels for Canadian- and U.S.-grown potato, including 'Russet Burbank'[13,21,26] and 'Superior',[27] but show wider variation and were more than 2.5-fold the greatest concentration previously reported for some macrominerals (K and P; Table 1). This supports observations that contents of K and P were affected by variety and site.[20]

'Goldrush' (QC), 'Green Mountain' (BA), and 'Freedom' and 'Highland Russet' (MB) had the greatest Ca content, which was almost twice the overall mean (Table 3). For K, Mg, and P contents, similar trends occurred; potato cultivars contained nutritionally significant concentrations, except for most cultivars grown at BA and several other cultivars grown at different locations. Potato cultivars with the greater Ca content also had greater K, Mg, and P values (Figure 1). 'Innovator' and 'Russet Burbank' grown at AB had significant Na content compared to other cultivars.

Values for trace minerals (mg/serving) varied widely between potato cultivars: from 14-fold (Fe, 0.47−6.49), 16-fold (Cu, 0.07−1.15; Zn, 0.18−3.02), and 86-fold (Se, 0.48−41.39 μg/148 g of FM) (Table 4). These values support the results of others.[27] Interestingly, the Zn content correlated well

Table 4. LS Mean Values for Trace Minerals (Cu, Fe, Se, and Zn) in One Serving (mg/148 g FM) of Potato Cultivars Grown at Different Canadian Sites[a]

cultivar	site	Cu	Fe	Se	Zn
Atlantic	BA	0.09^{ij3}	0.65^{efg3}	0.44^{d3}	0.24^{hi45}
Green Mountain	BA	0.93^{a-d1}	5.01^{abc12}	0.14^{d3}	2.09^{b-e1}
Goldrush	BA	0.11^{ij3}	0.60^{efg3}	0.31^{d3}	0.27^{hi45}
Kennebec	BA	0.10^{ij3}	0.52^{fg3}	1.26^{d3}	0.21^{i5}
Norland	BA	0.67^{c-g12}	4.02^{a-d12}	16.96^{a1}	2.10^{b-e1}
Onaway	BA	0.07^{j3}	0.47^{g3}	0.49^{d3}	0.18^{i5}
Russet Burbank	BA	0.69^{c-g12}	6.10^{abc1}	0.22^{d3}	1.40^{efg23}
Red Pontiac	BA	0.07^{j3}	0.54^{fg3}	0.22^{d3}	0.24^{hi45}
Sebago	BA	0.59^{d-g2}	3.01^{b-g23}	0.22^{d3}	1.02^{fgh23}
Shepody	BA	0.96^{abc1}	4.72^{abc12}	7.04^{c2}	1.59^{c-g12}
Superior	BA	0.09^{ij3}	0.73^{d-g3}	0.41^{d3}	0.30^{hi45}
Yukon Gold	BA	0.43^{ghi2}	3.02^{b-f23}	ND	0.83^{ghi34}
mean		0.42^{3}	2.72^{2}	2.33^{2}	0.92^{3}
Innovator	AB	1.03^{ab1}	3.99^{a-d2}	10.44^{bc1}	1.73^{c-f1}
Russet Burbank	AB	0.88^{a-e2}	5.19^{abc1}	8.83^{ba1}	1.48^{d-g1}
mean		0.95^{1}	4.59^{1}	9.64^{1}	1.60^{2}
Freedom	MB	0.52^{fg1}	3.86^{a-e2}	0.30^{d2}	2.23^{a-d1}
Highland Russet	MB	0.49^{fg1}	2.88^{c-g3}	0.43^{d2}	1.98^{b-e112}
Innovator	MB	0.09^{ij2}	0.69^{efg4}	0.26^{d2}	0.22^{i3}
Russet Burbank	MB	0.45^{g1}	4.80^{abc1}	10.75^{bc1}	1.79^{c-f2}
mean		0.39^{3}	3.05^{2}	2.78^{2}	1.55^{2}
Freedom	FL	1.15^{a1}	5.95^{abc1}	0.02^{d3}	2.35^{abc1}
Highland Russet	FL	0.13^{hij3}	0.65^{efg2}	0.51^{d2}	0.24^{hi3}
Innovator	FL	0.95^{abc12}	4.86^{abc1}	12.72^{ab1}	1.96^{b-e12}
Russet Burbank	FL	0.88^{a-e12}	3.82^{a-f1}	0.18^{d3}	1.89^{b-e12}
Victoria	FL	0.73^{b-g2}	6.49^{a1}	0.51^{d2}	1.56^{c-g2}
mean		0.77^{2}	4.35^{1}	2.55^{2}	1.60^{2}
Chieftain	QC	0.58^{efg2}	2.91^{c-g2}	ND	3.02^{a1}
Goldrush	QC	0.70^{c-g12}	6.30^{ab1}	0.17^{d1}	3.01^{a1}
Russet Burbank	QC	0.57^{efg2}	5.00^{abc12}	0.19^{d1}	1.83^{cde2}
Yukon Gold	QC	0.81^{a-f1}	5.08^{abc12}	0.29^{d1}	2.64^{ab12}
mean		0.67^{2}	4.82^{1}	0.21^{3}	2.63^{1}
overall mean		0.59	3.63	3.30	1.48

[a]ND = not detected. Means were compared using Tukey's honest significant difference test ($p \leq 0.05$); n = 5−10 replicates. Means with the same superscript letter or number are not significantly different. Superscript letters label differences between cultivars from different growing sites, and superscript numbers designate differences between cultivars from the same growing site. Differences between overall means of each growing site were illustrated by superscript numbers. For example, to examine differences among cultivars from field sites, superscript letters are compared. To investigate differences among cultivars at the same growing site, superscript numbers are compared.

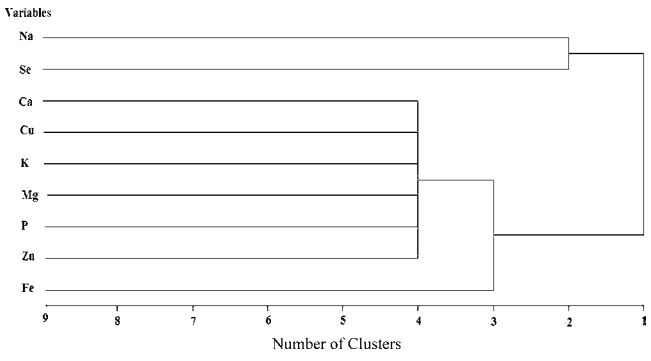

Figure 1. Tree dendrogram of clustering patterns of macro- and trace minerals of potato cultivars grown at five different sites in Canada.

Table 5. LS Mean Values for Macro- (Ca, K, Mg, Na, and P) and Trace (Cu, Fe, Se, and Zn) Minerals in One Serving (mg/148 g FM) from Potato Cultivars Grown at Different Canadian Sites[a]

cultivar	site	Ca	K	Mg	Na	P	Cu	Fe	Se	Zn
Freedom	MB	58.63^{a}	2173.1^{a}	170.81^{a}	4.95^{a}	346.41^{a}	0.52^{b}	5.95^{a}	0.30^{a}	2.23^{a}
Freedom	FL	36.37^{b}	1844.5^{b}	123.96^{b}	3.22^{b}	351.78^{a}	1.15^{a}	3.86^{b}	0.02^{a}	2.35^{a}
mean		47.50^{1}	2008.8^{1}	147.39^{1}	4.08^{234}	349.09^{1}	0.83^{1}	4.90^{1}	0.16^{2}	2.29^{1}
Goldrush	BA	4.97^{b}	260.5^{b}	14.79^{b}	1.00^{b}	48.47^{b}	0.11^{b}	0.60^{b}	0.31^{a}	0.27^{b}
Goldrush	QC	61.83^{a}	2342.7^{a}	178.25^{a}	4.59^{a}	449.17^{a}	0.70^{a}	6.30^{a}	0.17^{a}	3.01^{a}
mean		33.40^{23}	1301.6^{2}	96.52^{2}	2.79^{34}	248.82^{12}	0.41^{2}	3.45^{23}	0.26^{2}	1.64^{2}
Highland Russet	MB	55.10^{a}	2525.0^{a}	185.12^{a}	3.66^{a}	371.15^{a}	0.49^{a}	2.88^{a}	0.43^{a}	1.97^{a}
Highland Russet	FL	3.79^{b}	275.8^{b}	15.64^{b}	0.47^{b}	51.99^{b}	0.13^{b}	0.65^{b}	0.51^{a}	0.24^{b}
mean		29.44^{3}	1400.4^{2}	100.38^{2}	2.07^{4}	211.57^{3}	0.31^{2}	1.76^{4}	0.47^{2}	1.11^{3}
Innovator	AB	41.95^{a}	1985.2^{a}	155.22^{a}	13.61^{a}	331.10^{b}	1.03^{a}	3.99^{a}	10.44^{b}	1.73^{a}
Innovator	MB	4.93^{b}	283.00^{b}	14.96^{b}	0.74^{b}	63.79^{c}	0.09^{b}	0.69^{b}	0.26^{c}	0.22^{b}
Innovator	FL	35.78^{a}	1949.8^{a}	155.02^{a}	2.39^{b}	366.03^{a}	0.95^{a}	4.86^{a}	12.72^{a}	1.96^{a}
mean		27.55^{3}	1406.0^{2}	108.40^{2}	5.58^{12}	253.64^{23}	0.69^{1}	3.18^{3}	6.56^{1}	1.30^{23}
Russet Burbank	BA	44.95^{a}	1683.9^{a}	126.96^{a}	3.81^{b}	268.74^{a}	0.69^{ab}	6.10^{a}	0.22^{b}	1.40^{a}
Russet Burbank	AB	37.67^{a}	2224.5^{a}	161.39^{a}	18.93^{a}	381.20^{a}	0.88^{a}	5.19^{a}	8.83^{a}	1.48^{a}
Russet Burbank	MB	43.03^{a}	2046.3^{a}	140.70^{a}	5.89^{b}	301.54^{a}	0.45^{b}	4.80^{a}	10.75^{a}	1.79^{a}
Russet Burbank	FL	35.00^{a}	2061.4^{a}	148.69^{a}	2.41^{b}	370.55^{a}	0.88^{a}	3.82^{a}	0.18^{b}	1.89^{a}
Russet Burbank	QC	44.27^{a}	1683.9^{a}	113.99^{a}	4.39^{b}	268.74^{a}	0.57^{b}	5.00^{a}	0.19^{b}	1.83^{a}
mean		40.62^{12}	2015.9^{1}	141.05^{1}	7.32^{1}	338.50^{1}	0.71^{1}	4.98^{1}	5.53^{1}	1.66^{2}
Yukon Gold	BA	27.81^{a}	1875.0^{b}	127.23^{b}	3.21^{a}	256.42^{b}	0.43^{b}	3.02^{b}	ND	0.83^{b}
Yukon Gold	QC	31.38^{a}	2496.5^{a}	171.11^{a}	6.29^{a}	330.68^{a}	0.81^{a}	5.08^{a}	0.29	2.64^{a}
mean		30.36^{3}	2318.9^{1}	158.57^{1}	5.41^{123}	309.46^{12}	0.70^{1}	4.49^{12}	0.29^{2}	2.12^{1}

[a]Means were compared using Tukey's honest significant difference test ($p \leq 0.05$); n = 5−10 replicates. Means were compared for differences within each cultivar from different growing sites. Means with the same superscript letter were not significantly different.

with the macrominerals Ca, K, Mg, and P (Figure 1). All trace minerals were correlated moderately, except for weak correlations among Se and Fe, Se and Zn, and Na and Zn.

The range in Fe and Zn contents in the Canadian-grown potato cultivars (0.47−6.49 and 0.18−3.02 mg per serving, respectively) was greater than that reported for 48 Andean potato cultivars (0.38−0.95 and 0.43−0.59 mg/148 g of FM, respectively).[22] 'Russet Burbank' was unique with consistently high concentrations of Ca, Fe, K, Mg, P, and Zn across all five growing sites (Table 5). The other cultivars were clearly inconsistent across locations, with good mineral content at one planting location but not necessarily at all sites.

A wide range of variation was seen for minerals among the different potato cultivars (Tables 3 and 4). Examination of the average mineral content for each cultivar at all of the growing sites showed that 'Freedom', 'Russet Burbank', and Yukon Gold' had significantly greater concentrations of almost all tested minerals (Table 5), except for Na (greater in 'Russet Burbank' compared to 'Freedom'), and Zn (greater in 'Freedom' and 'Yukon Gold' compared to 'Russet Burbank'). Also, 'Innovator' had considerable concentrations of Cu and Na. 'Goldrush' had similar P concentrations to the four other cultivars but greater than 'Highland Russet'. The five cultivars in Table 5 had similar contents of Se at all growing sites. In general, seven cultivars, including 'Freedom' (MB), 'Goldrush' (QC), 'Russet Burbank' (AB), 'Shepody' (BA), 'Highland Russet' (MB), 'Innovator' (AB and FL), and 'Yukon Gold' (QC), showed significant content of Ca, K, Mg, Na, P, Cu, and Zn minerals.

Differences among Cultivars at Each Site. Significant differences were found in the mineral content of one serving of potato cultivars grown at different sites across Canada. Most mineral (Ca, Cu, Fe, K, Mg, Na, and P) values were greater at the AB site compared to the other four sites (Tables 4 and 5). However, the content of some minerals (Ca, Fe, K, and P) was not significantly different between growing sites in AB and QC.

At all five growing sites, 'Russet Burbank' showed similar content for almost all minerals, except Na (greatest at AB), Se (least at AB and not detected at MB and QC), and Cu (less at QC) (Table 5). This finding supports the observations of others, who noted similar mineral concentrations in this cultivar, despite differences in fertilization rates.[28] This stability in mineral content at very different locations underlines the genetic component and may explain, in part, its remarkable success as a table and processing cultivar. It has been reported that the growing site did not affect the content of boron (B), Cu, Fe, I, Mg, manganese (Mn), molybdenum (Mo), and Zn of several potato cultivars, including Russet Burbank.[13] However, in the present study, the overall impact of the growing location on the mineral content was shown to be important because this affected the mineral content of most cultivars.

Overall, the mineral content of cultivars from the AB site showed the greatest content of Cu, Mg, and Na, while the QC site showed the greatest content of Zn. Both AB and QC sites showed the greatest content of Ca, Fe, K, and P. The BA site had the least average mineral content for all of the potato cultivars, apart from Russet Burbank. The latter finding may be explained by the shorter growing season used for seed tubers, which are generally harvested earlier and at a smaller size than table or processing tubers.

Contribution of Select Minerals to the % RDI. Results of select minerals (Ca, Cu, Fe, K, Mg, Na, P, Se, and Zn) were interpreted in terms of the daily contribution that one serving of potato (148 g of FM) would make to the diet (Table 6). In terms of the contribution of the select minerals toward the % RDI, the ranges for macrominerals were as follows: Ca, 0.32−6.18; K, 6.39−72.14; Mg, 3.60−52.89; Na, 0.01−0.79; and P, 4.22−44.92, and the ranges for trace minerals were as follows:

Table 6. Percent Contribution of Macro- (Ca, K, Mg, Na, and P) and Trace (Cu, Fe, Se, and Zn) Minerals to Recommended Dietary Intake/Day for Adult Males from 19 to 50 Years of Age[3,25] Based on One Serving (148 g of FM) of Potato[a]

cultivar	site	Ca	K	Mg	Na	P	Cu	Fe	Se	Zn
Atlantic	BA	0.39	8.37	4.03	0.02	4.73	4.50	4.33	0.80	1.60
Green Mountain	BA	5.35	48.15	31.21	0.34	34.90	46.50	33.40	0.25	13.93
Goldrush	BA	0.50	7.44	4.23	0.04	4.85	5.50	4.00	0.56	1.80
Kennebec	BA	0.33	6.69	4.35	0.01	5.04	5.00	3.47	2.29	1.40
Norland	BA	2.13	58.65	43.81	0.12	41.14	33.50	26.80	30.84	14.00
Onaway	BA	0.32	6.39	4.26	0.02	4.22	3.50	3.13	0.89	1.20
Russet Burbank	BA	4.50	54.21	36.27	0.16	33.56	34.50	40.67	0.40	9.33
Red Pontiac	BA	0.44	6.85	3.60	0.04	4.29	3.50	3.60	0.40	1.60
Sebago	BA	2.26	52.40	30.85	0.16	26.29	29.50	20.07	0.40	6.80
Shepody	BA	2.56	56.77	41.89	0.08	39.04	48.00	31.47	12.80	10.60
Superior	BA	0.40	6.50	4.13	0.02	4.49	4.50	4.87	0.75	2.00
Yukon Gold	BA	2.78	53.57	36.35	0.13	25.64	21.50	20.13	ND	5.53
mean		1.83	30.50	20.42	0.10	19.02	20.00	16.33	4.24	5.82
Innovator	AB	4.20	56.72	44.35	0.57	33.11	51.50	26.60	18.98	11.53
Russet Burbank	AB	3.77	63.56	46.11	0.79	38.12	44.00	34.60	16.05	9.87
mean		3.98	60.14	45.23	0.68	35.62	47.75	30.60	17.53	10.70
Freedom	MB	5.86	62.09	48.80	0.21	34.64	26.00	25.73	0.55	14.87
Highland Russet	MB	5.51	72.14	52.89	0.15	37.12	24.50	19.20	0.78	13.20
Innovator	MB	0.49	8.08	4.27	0.03	6.38	4.50	4.60	0.47	1.47
Russet Burbank	MB	4.30	58.47	40.20	0.23	30.15	22.50	32.00	19.55	11.93
mean		4.04	50.20	36.54	0.16	27.07	19.38	20.38	5.05	10.37
Freedom	FL	3.64	52.70	35.42	0.13	35.18	57.50	39.67	0.04	15.67
Highland Russet	FL	0.38	7.88	4.47	0.02	5.20	6.50	4.33	0.93	1.60
Innovator	FL	3.58	55.71	44.29	0.10	36.60	47.50	32.40	23.13	13.07
Russet Burbank	FL	3.50	58.90	42.48	0.10	37.06	44.00	25.47	0.33	12.60
Victoria	FL	3.32	51.48	33.90	0.17	30.38	36.50	43.27	0.93	10.40
mean		2.88	45.33	32.11	0.10	28.88	38.60	29.03	4.64	10.67
Chieftain	QC	3.04	38.53	30.05	0.19	24.64	29.00	19.40	ND	20.13
Goldrush	QC	6.18	66.93	50.93	0.19	44.92	35.00	42.00	0.31	20.07
Russet Burbank	QC	4.43	48.11	32.57	0.18	26.87	28.50	33.33	0.35	12.20
Yukon Gold	QC	3.14	71.33	48.89	0.26	33.07	40.50	33.87	0.53	17.60
mean		4.20	56.23	40.61	0.21	32.37	33.60	32.15	0.38	17.50
overall site mean		3.39	48.48	34.98	0.25	28.59	31.87	25.70	6.37	11.01
cultivar means										
Freedom	mean	4.75	57.40	42.11	0.17	34.91	41.75	32.70	0.30	15.27
Goldrush	mean	3.34	37.19	27.58	0.12	24.89	20.25	23.00	0.44	10.94
Highland Russet	mean	2.95	40.01	28.68	0.09	21.16	15.50	11.77	0.86	7.40
Innovator	mean	2.04	31.90	24.28	0.07	21.49	26.00	18.50	11.80	7.27
Russet Burbank	mean	4.10	56.65	39.53	0.29	33.15	34.70	33.21	7.34	11.19
Yukon Gold	mean	2.96	62.45	42.62	0.20	29.36	31.00	27.00	0.53	11.57

[a]These are organized first by cultivar within sites and then across sites.

Cu, 3.50−57.50; Fe, 3.13−43.27; Se, 0.96−82.78; and Zn, 1.20−20.13. The overall average contribution to the % RDI of potato cultivars was as follows: Ca, 3.39; K, 48.48; Mg, 34.98; Na, 0.25; P, 28.59; Cu, 31.87; Fe, 25.70; Se, 24.41; and Zn, 11.01.

'Freedom' and 'Highland Russet' (MB), 'Goldrush' (QC), and 'Green Mountain' (BA) contributed up to 6% of the RDI of Ca compared to the overall mean of all examined cultivars (Table 6). This is a relatively trivial contribution of calcium; potatoes are not generally considered to be major suppliers of this macromineral, although some exceptions occur.[3,13] A substantial contribution to the % RDI of K was provided by 'Highland Russet' (MB) (72%), 'Yukon Gold' (QC) (71%), and 'Goldrush' (QC) (66.93%). 'Highland Russet' (MB) (52.89%) and 'Goldrush' (QC) (50.93%) contributed the most to the % RDI of Mg. The overall mean contribution to the % RDI of Na was a trivial 0.25%. 'Norland' (BA) and 'Goldrush' (QC) contributed 41.14 and 44.92% of the RDI of P, respectively.

A serving of potato can contribute considerably toward the % RDI of Cu (Table 6). 'Freedom', 'Innovator' (FL and AB), and 'Shepody' (BA) provided 57, 51, 47, and 48%, respectively, of the RDI of Cu. The present findings show that 'Goldrush' (QC), 'Russet Burbank' (BA), and 'Victoria' (FL) could contribute 40−43% of the RDI for Fe. The average contribution of Fe (25.70%) is far greater than the 6% of the U.S. and Canadian recommended daily allowance (RDA) reported for some cultivars[29] and in concert with the higher end of the range (10−54.5% of the dietary iron intake) reported for the Jancko Anckanchi genotype (Ajanhuiri group), described as a "high-iron" potato genotype.[18]

The % RDI of Se was contributed mainly by 'Russet Burbank' (BA), 'Victoria' (FL), and 'Highland Russet' (MB), which contained from 74.28 to 82.72% of the RDI of Se. The

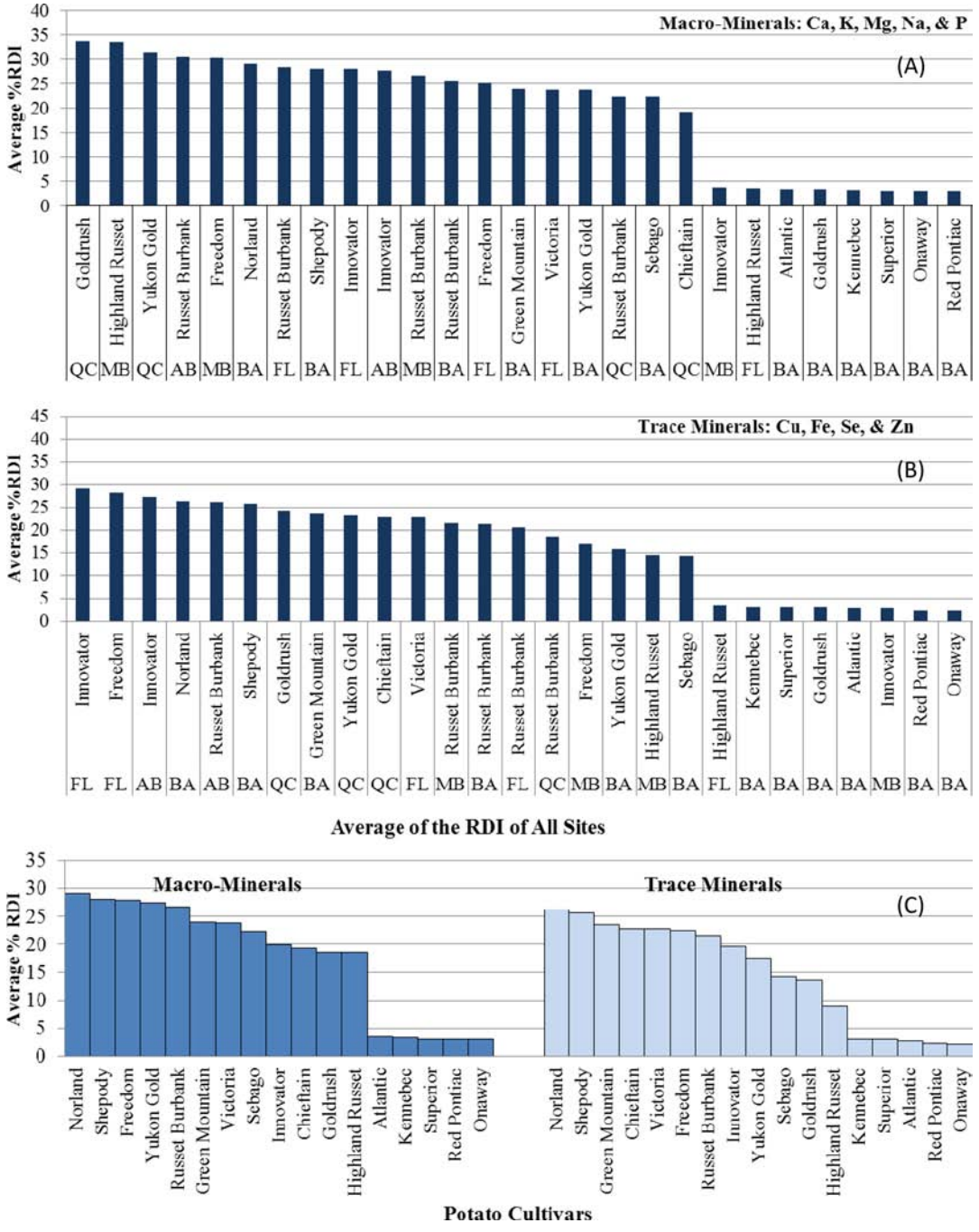

Figure 2. Cultivar index: average results of totals of % RDI provided by potato cultivars collected from five locations in Canada: (A) macrominerals, Ca, K, Mg, Na, and P contents, (B) trace minerals, Cu, Fe, Se, and Zn, and (C) average of % RDI of macro- and microminerals of potato cultivars from all growing locations.

overall average contribution to the % RDI of Se of potato cultivars was 24.41%. 'Chieftain' and 'Goldrush' (QC) contribute about 20% to the Zn RDI. By comparison, one serving of '705264-Roscalena' (Andigenum group) provided 8–37% of the RDI of Zn,[18] while in our study, potato averaged a much smaller contribution (11.01%) toward the RDI of Zn (Table 6).

In terms of the assessment of factors that affected the average contribution toward dietary intake of minerals, the planting site exerted a major impact. Potato cultivars collected from the AB site could contribute the greatest % RDI for Cu, K, Mg, Na, and P. Cultivars obtained from the QC site could contribute the greatest % RDI for Ca, Fe, and Zn. Potatoes obtained from the BA site could contribute the least % RDI for all minerals, except for Se. Cultivar exerted a significant impact on the potential contribution to the % RDI because 'Goldrush' (QC), 'Russet Burbank' (AB), and 'Yukon Gold' (QC) showed the greatest potential contribution toward the % RDI for most of the studied minerals (Figure 2), which was in agreement with Luis et al.,[30] who noted substantial mineral composition differences among cultivars. Overall, 'Russet Burbank', with its relatively greater mineral composition and remarkable stability of mineral composition from site to site, could be recommended as the

best dietary source for essential minerals among the potato cultivars tested.

A consumer who eats one serving of potato per day could receive from 30 to 48% of the RDI for macrominerals, except for Ca and Na and from 6 to 82% of the RDI for trace minerals. 'Freedom', 'Yukon Gold', and particularly the very stable mineral source 'Russet Burbank' contributed the most toward the % RDI for minerals. One serving per day of these latter cultivars could provide from 30 to 62% of the RDI for the macrominerals Mg, P, and K, which is a 2-fold greater contribution than the overall site average. The above cultivars can also contribute from 12 to 82% of the RDI for the trace minerals Cu, Fe, Se, and Zn, which is a 1.3−3.4-fold greater amount than the overall site average. Thus, dependent upon the cultivar consumed, potato cultivars grown in Canada could provide a good source of minerals on a per serving basis, especially of minerals that tend to be deficient in the Canadian diet, such as Cu, Fe, Mg, and Zn.[9−12,31] For example, consumption of one serving (148 g of FM) of 'Goldrush' (QC) can provide on average up to 51, 45, 42, and 20% of the daily requirements of Mg, P, Fe, and Zn for Canadians, respectively. On the other hand, potatoes do not contribute significantly to the RDI of Ca and I, which is in line with results reported elsewhere.[13]

The contributions of potato intake toward meeting mineral requirements may also be significant because of a relatively higher mineral bioavailability attributed to potatoes versus other major food crops, such as legumes, whole grains, and nuts.[17,32,33] Potatoes generally contain higher concentrations of ascorbate and organic acids[15] that promote mineral absorption and lower concentrations of phytates[16] and oxalates[15] that form insoluble mineral precipitates that limit mineral absorption within the gut. Phytic acid is present in whole-grain cereals and legumes at approximately 1% on a wet weight basis[32] versus 0.01−0.1% wet weight content in potatoes.[16] Likewise, the wet weight oxalate content of 0.02−06% in potatoes[15] is exceeded on average by several fold higher concentrations in nuts and legumes.[34] Fairweather-Tait[36] showed moderate bioavailability of non-heme iron from potato in rat balance studies as well as better solubilization of potato-derived Fe in gastric juices versus other vegetable foods. However, it is possible that mineral bioavailability could vary significantly among cultivars depending upon their relative content of mineral inhibitors, such as phytates and polyphenols, and mineral enhancers, such as ascorbate.

Discriminant Function and Cluster Analyses. Cluster analysis showed two major groups. The first group was comprised of Na and Se; their early clustering (joining) refers to strong correlation coefficients (high similarity) (Figure 1). The second group indicates strong correlation coefficients between Ca, Cu, K, Mg, P, and Zn. Na was clustered with the second group but with low correlation. Several combinations of mineral elements (macrominerals, Ca, K, Mg, and P, and/or trace minerals, Cu, Fe, Na, Se, and Zn, or various assorted groups of macro- or trace minerals) were used for the canonical discriminant analysis but did not show clustering of cultivars or growing sites. This suggests that both the genotype and growing location (with its associated agricultural practices) were important.

Canadian-Grown Potato Cultivars Contain Substantial Essential Mineral Content. Estimation of the mineral content of potato cultivars from various Canadian growing sites is important because the mineral content per serving (mg/148 g of FM) of specific potato cultivars was clearly affected by growing region. Both the potato industry and consumers can benefit from information regarding the relative mineral contribution of this major staple food item grown at different sites in Canada. However, it is interesting to note that cultivars from the same growing site did not cluster together. This latter observation suggests a stronger effect of genotype compared to growing site. In fact, the growing site was clearly less important for 'Russet Burbank', which was more stable in mineral content than any other cultivar examined across all planting locations. For the other cultivars, growing site and agricultural practices also had a strong effect on the mineral content. Cultivars grown at the Alberta (AB) site had the greatest average content of Cu and Mg per serving. Also, cultivars grown at the AB and QC sites had significantly greater average content of Ca [along with cultivars in Manitoba (MB)], Fe and P [along with cultivars grown in FL, New Brunswick (NB)], and K compared to other sites. The greatest average Zn levels were found in the cultivars grown in QC.

This study highlights the very important contribution of potato to the Canadian diet in terms of mineral nutrition, particularly because the estimated consumption of potatoes in the Canadian population is substantial (190.66 g/person/day).[1] The provision of essential minerals by potato intake could also be important in many parts of the world where potato is a staple food. The present work underlines the importance of using specific cultivar names, such as 'Russet Burbank' or 'Yukon Gold' for the benefit of consumers who could select cultivars with better nutritional content in terms of essential minerals.

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