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Research Article

Contents of micronutrients in different vegetables grown in different locations in Tanzania: implications for soil fertility and nutrition potential of the vegetables

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ABSTRACT
Samples of twenty two different vegetables were collected from different locations in Tanzania, in three replicates, with the objective of determining their micronutrient contents. The samples were washed, dried, ground, and ashed in a muffle furnace. The ash was dissolved in 10% nitric acid and the extracts made to volume in 25-ml volumetric flasks. Copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) were determined using atomic absorption spectrophotometry. The data were subjected to analysis of variance. Results showed that the different types of vegetables contained different quantities of the nutrients. For example, Cu ranged from 3.75 mg/kg in egg plant to 8.26 mg/kg in sweet potato leaves. Zinc ranged from 13.54 mg/kg in African egg plant to 49.89 mg/kg in cassava leaves (rubber type). Manganese ranged from 15.21 mg/kg in egg plant to 137.19 mg/kg in cassava leaves (cassava) and Fe ranged from 102.08 in African egg plant to 478.11 mg/kg in Chinese cabbage. Within a given type of vegetable, nutrient contents were different across locations of sampling. For example, Cu in amaranthus from Morogoro varied from 6.25 mg/kg to 7.5 mg/kg, while that from Mbeya varied from 5 mg/kg to 10.62 mg/kg. Zinc in amaranthus from Mbeya varied from 25.31 mg/kg to 40 mg/kg, while from Vumari-Same Zn varied from 30.31 mg/kg to 39.06 mg/kg. Manganese in amaranthus from Mbeya varied from 89.37 mg/kg to 110 mg/kg, while from Morogoro Mn varied from 31.25 mg/kg to 35.62 mg/kg. Iron in amaranthus from Vumari-Same varied from 318.75 mg/kg to 409.37 mg/kg, while from Morogoro Fe varied from 425 mg/kg to 531.25 mg/kg. Similar variations were observed in the other types of vegetables. Copper was rated as being low (for pregnant and lactating women). Zinc was generally rated as being low; the rest of the nutrients in the vegetables were deemed adequate for human nutrition.

KEYWORDS: *Vegetables, micronutrient contents, copper, zinc, manganese, iron, locations, soil fertility, Tanzania*

INTRODUCTION

Good nutrition of human beings depends on intake of adequate quantities of the different nutrients found in the foods consumed. Soils, as the primary source of nutrients absorbed by plants, usually contain different quantities of nutrients across different areas. For example, Kabata–Pendias and Pendias [1] reported zinc (Zn) values ranging from 17 to 125 mg/kg as being background total contents for large numbers of surface soils in different countries. But available, or extractable, quantities are usually much lower than the total contents. Lindsay and Novell [2] proposed a critical level of DTPA-extractable Zn to be 0.5 to 1.0 mg/kg for most agricultural soils.

In Tanzania, DTPA–extractable Zn levels of 1.9 to 7.9 mg/kg have been reported in Mbeya [3]. However, other soils have shown much lower levels, as low as 0.2 mg/kg or lower, as was observed for

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some soils in Morogoro region, and others in Njombe, both in Tanzania [4; Semu, unpublished data]. With such low levels, many crop plants may not extract enough Zn to satisfy human/animal nutrition requirements.

In soils, total copper (Cu) contents range from traces (sandy soils of U.S.S.R and certain tropical soils) to 200 – 250 mg/kg (vertisols of India); the average range being from 10 to 50 mg/kg [5]. The variations are mostly due to the different Cu contents of the parent rocks on which the soils have been formed. Many tropical (including Tanzanian) soils are not well characterized with respect to their copper contents, but could be expected to lie within the ranges reported elsewhere. The implication is that crops grown on soils with varying contents of nutrients could also be expected to show wide variations in nutrient contents, with implications on their adequacy, or otherwise, for good human/animal nutrition.

Despite iron constituting about 5% of the earth's crust, resulting in abundant total iron levels in soils, iron deficiencies in crops may occur due to antagonistic relationships in soil between iron and other micronutrients, for example the manganese-induced iron deficiency [6].

Most soils display relatively high levels of fertility in the early years of cultivation, which leads to high crop yields with adequate nutritional value. But with over-exploitation of soil and land resources due to long-term cultivation without fertilizer use, some of the productive soils have been degraded, which leads not only to low crop yields but also to low crop nutrient levels inadequate for human and/or animal nutrition. Nutrients play important roles in metabolism as related to nutrition and other body functions. For example, zinc is required for the catalytic activity of many enzymes, and it plays a role in immune function, protein synthesis, and wound-healing, among others. Iron (Fe) is an essential component for metabolism, and is a component of red blood cells. Iron deficiency may cause anemia, leading to fatigue, body weakness and other health ailments. Copper plays a role in bones, connective tissues, energy production in the cells, immune responses, and in reproductive and nervous systems. It is important, therefore, that crops should contain the different nutrients at levels that will meet the recommended dietary allowances for proper body functioning.

Vegetables of different types are among the mostly consumed crops that may supplement cereals in providing micronutrients. But, like other crops, vegetables may also contain different levels of nutrients as a result of different nutrient levels in soils as well as the crops' inherent differences in nutrient absorption ability. However, the levels of nutrients in local leafy vegetables have not been quantified in Tanzania.

The research reported here was undertaken to survey the nutrient (Fe, Cu, Zn and Mn) contents in different vegetables, including local types, to assess variations of those nutrients with geographical locations/soils where the vegetables were grown, and to determine whether those vegetables may supply adequate levels of nutrients for human nutrition when compared to recommended ratings.

MATERIALS AND METHODS

Vegetable sample collection

Twenty two samples of different vegetables were collected from different locations in Tanzania (Table 1). Each kind of vegetable at each location was sampled in three replicates.

TABLE 1: *Types of vegetables sampled*

Common name of vegetable	Scientific name	Kiswahili name	Area/district where vegetable was collected
1.Cassava leaves	*Manihot esculentum*	Kisamvu (mpira)	Kingulwira, Morogoro
2. "	"	" (mhogo)	Mazimbu, Morogoro
3.Pumpkin leaves	*Curcubita spp*	Majani ya maboga	Bigwa, Morogoro
4. "	"	"	Uyole, Mbeya
5.Amaranthus	*Amaranthus spp*	Mchicha	Mazimbu, Morogoro
6. "	"	"	Vumari, Same
7. "	"	"	Uyole, Mbeya
8.Night black shade	*Solanum nigram*	Mnavu	Mazimbu, Morogoro
9 "	"	"	Mwembe, Same
10. "	"	"	Uyole, Mbeya
11.Sweet potato leaves	*Ipomea batatas*	Matembele	Kisiwani, Same
12. "	"	"	Vumari, Same
13. "	"	"	Bigwa, Morogoro
14.Chinese cabbage	*Brassica chinensis*	Chainizi	Uyole, Mbeya
15. "	"	"	Mazimbu, Morogoro
16. Egg plant	*Solanum melongena*	Biringanya	Mlali, Morogoro
17. Okra	*Abelmoschus esculentus*	Bamia	Mikese, Morogoro
18.African eggplant	*Solanum macrocarpon*	Nyanya chungu	Mgeta, Morogoro
19. Cowpea leaves	*Vigna unguiculata*	Majani ya kunde	Mindu, Morogoro
20. Jute	*Corchorus olitorius*	Mlenda	Matombo, Morogoro
21. Black jack	*Bidens pilosa*	Mashona nguo	Mazimbu, Morogoro
22.Abyssinian mustard	*Brassica carinata*	Figiri	Uyole, Mbeya

Sample preparation and analysis

These samples were taken to the laboratory at the Department of Soil Science, Sokoine University of Agriculture, Morogoro, Tanzania, where they were rinsed in distilled water to remove adhering soil/dust particles, and oven dried at 60°C for 3 days. The samples were ground to form a powder using a laboratory grinding mill (cyclotec 1093 sample mill). From each sample 2g of the powder were weighed into a porcelain crucible and ashed in a muffle furnace at 500°C for three hours. The ash was dissolved in 10% nitric acid and quantitatively transferred to a 25-ml volumetric flask and made to volume using distilled water. The digests/extracts were used in the determination of Cu, Zn, Mn and Fe using an atomic absorption spectrophotometer (AAS). The wavelengths for Cu, Zn, Fe and Mn were 324.7nm, 213.9nm and 248.3 nm, respectively. The concentrations of the nutrients in the digest/extract were converted to mg nutrient/kg vegetable (dry basis).

Data were subjected to analysis of variance using the completely randomized design in the case of the entire data set involving all the vegetable types, or the randomized complete block design within a given type of vegetable. Means within vegetable types/varieties were compared (or ranked) using the Tukey's Studentized Range Test.

RESULT AND DISCUSSION

Copper contents in the different vegetables

The copper contents of the vegetables are shown in Table 2. Generally, the different types of vegetables did not differ much in copper contents. For example, in the 13 vegetable types tested, the copper contents ranged from 5 mg/kg to 6.87 mg/kg, except for sweet potato leaves which ranked the highest (8.26 mg/kg), and egg plant which contained the lowest (3.79 mg/kg). However, the contents in a given type of vegetable seemed to differ with location. For example, the pumpkin leaves from Uyole, Mbeya, contained a minimum of 3.12 mg Cu/kg and maximum of 4.37 mg Cu/kg while the same type of vegetable from Bigwa, Morogoro, showed a range of 6.87mg/kg to 10.62mg/kg. Vegetables in Tanzania are yet to be analyzed to indicate the levels of Cu that may insure adequate nutrition. Mills and Jones [7] reported a range of 5 - 15 ppm for spinach and lettuce, and 5 - 10 ppm for broccoli. Maynard and Hochmuth [8] suggested the critical level for Chinese cabbage to be 10 – 15 mg/kg. Geraldson *et al.* [9] indicated the normal range of Cu in mature trifoliate leaves of bean to be 15 - 30mg/kg. Typical concentrations of Cu in plants range from 1 to 12 mg/kg dry weight [10]. The values reported herewith (Table 2) seem to fit in the cited ranges.

The different Cu contents reported here may be due, in part, to inherent differences between vegetable types as well soil types, which vary from place to place. The differences in Cu contents within the same type of vegetable may be a result that the samples from different geographical locations may actually constitute different (local) varieties (landraces) of that type of vegetable. Additionally, they may not have been all sampled at the same stage of growth.

TABLE 2: *Copper contents (mg/kg) in different types of vegetable sampled from different areas*

Type of vegetable	Location sampled	n	Minimum content at location	Maximum content at location	Location mean	Standard error	Vegetable type mean
Pumpkin leaves	Uyole - Mbeya	3	3.12	4.37	3.54	0.41	
	Bigwa - Morogoro	3	6.87	10.62	8.33	1.15	5.93 ab
Amaranthus	Uyole - Mbeya	3	5	10.62	7.41	1.67	
	Mazimbu-Morogoro	3	6.25	7.5	7.5	0.36	
	Vumari - Same	3	3.75	6.25	4.79	0.75	6.36 ab
Night black shade	Uyole - Mbeya	3	8.12	10.62	9.79	0.83	
	Mazimbu-Morogoro	3	1.25	7.5	2.08	0.55	
	Mwembe- Same	3	3.12	8.75	5	1.87	5.62 ab
Chinesse cabbage	Uyole - Mbeya	3	3.12	8.12	5.62	1.44	
	Mazimbu-Morogoro	3	4.87	7.87	6.33	0.86	5.97 ab
Abyssinian mustard	Uyole - Mbeya	3	5.62	6.25	6.04	0.2	6.04 ab
Cassava leaves(rubber)	Kingulwira-Morogoro	3	6.25	7.5	6.87	0.36	6.87 ab
Cassava leaves(cassava)	Mazimbu-Morogoro	3	5	6.25	5.41	0.41	5.41 ab
Sweet potato	Bigwa - Morogoro	3	4.37	9.37	7.5	1.57	
	Kisiwani - Same	3	5.62	9.37	7.08	1.15	
	Vumari - Same	3	6.25	12.5	10.2	1.98	8.26 a
Egg plant	Mlali - Morogoro	3	3.12	4.37	3.75	0.36	3.75 b
Okra	Mikese – Morogoro	3	5	6.87	5.62	0.62	5.62 ab
African egg plant	Mgeta- Morogoro	3	5.62	6.25	6.04	0.2	6.04 ab
Cowpea leaves	Mindu- Morogoro	3	3.12	6.25	5	0.95	5 ab
Black jack	Mazimbu-Morogoro	3	5.62	11.87	7.91	1.98	7.91 a

Means within the vegetable type column followed by the same letter are not significantly different ($P = 0.05$) according to Tukey's test.

According to ratings by Eck and Wilson [11], the concentrations of Cu found in vegetables in the present study may be sufficient for the nutrition of all ages, except pregnant and lactating women.

Zinc contents in the vegetables

The zinc contents of the vegetables are shown in Table 3. Generally, the different types of vegetables did not differ much, statistically, in Zn contents. For example, looking at the vegetable type mean column, while the highest Zn concentration was in cassava leaves (49.89 mg/kg) and the lowest in African egg plant (13.54 mg/kg), most of the vegetables' Zn contents lay between 22.5 mg/kg and 38.15 mg/kg. However, the contents in a given type of vegetable differed with location. For example, Chinesse cabbage from Uyole, Mbeya, contained a minimum of 43.75 mg/kg and maximum of 48.12 mg/kg while the same type of vegetable from Mazimbu, Morogoro, contained a range of 23.75 mg/kg to 41.56 mg/kg.

As for Cu, the reasons for differences in Zn contents between the different vegetables may lie in inherent differences between vegetable types, fertility status of the soils from where they grew, and differences between varieties of the same vegetable. Mills and Jones [7] reported different levels of zinc in different vegetables, e.g. 20 to 75 mg/kg for spinach and lettuce, and 45 – 90 mg/kg for broccoli. The typical natural zinc concentrations in plants vary from 12 to 60 mg/kg dry weight [10]. Maynard and Hochmuth [8] suggested 50 mg Zn/kg as being the critical concentration for Chinese cabbage. Based on the results of this study, concentration of zinc in Chinese cabbage and all the other vegetables (with the exception of that of cassava [rubber type]), were below the critical concentration rated for providing adequate nutrition. This low content is of particular concern because vegetables are usually consumed as a minor component in a diet, and may not feature in every meal consumed. Therefore, the gross quantities consumed in a day may, overall, be low, leading to low consumption of Zn and/or any other deficient nutrient(s).

TABLE 3: *Zinc contents (mg/kg) in different types of vegetable sampled from different areas*

Type of vegetable	Location sampled	n	Minimum contet at location.	Maximum content at location.	Location mean	Standard error	Vegetable type mean
Pumpkin leaves	Uyole – Mbeya	3	33.43	43.43	39.79	3.13	
	Bigwa – Morogoro	3	21.25	31.87	27.39	3.17	33.59 ab
Amaranthus	Uyole – Mbeya	3	25.31	40	31.97	4.29	
	Mazimbu-Morogoro	3	20.62	26.87	23.95	1.81	
	Vumari – Same	3	30.31	39.06	33.64	2.72	29.86 bc
Night black shade	Uyole – Mbeya	3	35	44.37	40	2.72	
	Mazimbu-Morogoro	3	15.31	15.62	15.41	0.1	
	Mwembe- Same	3	14.21	18.75	16.09	1.36	23.83 bc
Chinesse cabbage	Uyole – Mbeya	3	43.75	48.12	45.93	1.26	
	Mazimbu-Morogoro	3	23.75	41.56	30.36	5.62	38.15 ab
Abyssynian mustard	Uyole – Mbeya	3	32.18	38.43	35.62	1.83	35.62 ab
Cassava leaves (rubber)	Kingulwira-Morogoro	3	41.87	54.68	49.89	4.03	49.89 a
Cassava leaves (cassava)	Mazimbu-Morogoro	3	16.87	46.87	29.89	8.88	29.89 bc
Sweet potato leaves	Bigwa – Morogoro	3	13.75	14.68	14.27	0.27	
	Kisiwani – Same	3	16.25	18.12	17.29	0.55	
	Vumari – Same	3	11.56	12.5	11.97	0.27	14.51 c
Egg plant	Mlali – Morogoro	3	12.5	15.62	14.27	0.92	14.27 c
Okra	Mikese – Morogoro	3	24.68	49.37	35.72	7.24	35.72 ab
African eggplant	Mgeta- Morogoro	3	12.81	15	13.52	0.72	13.54 c
Cowpea leaves	Mindu- Morogoro	3	15.62	30.93	25.62	5	25.62 bc
Jute	Mtombo- Morogoro	3	15.93	26.56	22.49	3.31	22.5 bc
Black jack	Mazimbu-Morogoro	3	25	48.12	34.06	7.12	34.06 ab

Means within the vegetable type column followed by the same letter are not significantly different ($P=0.05$) according to Tukey's test.

Manganese contents in the vegetables

The manganese contents of the vegetables are shown in Table 4. Generally, there were some differences in Mn contents in the different types of vegetables; the highest value of 137.19 mg/kg was from cassava leaves and the lowest value (15.21 mg/kg) was from African egg plant. But contents in most of the vegetables ranged from 54.38 mg/kg to 100.27 mg/kg.

However, the Mn contents in a given type of vegetable seemed to differ with location. For example, black night shade from Uyole, Mbeya, contained a minimum of 102.5 mg/kg and maximum 124.84 mg/kg while the same type of vegetable from Mazimbu, Morogoro, contained a minimum of 58.75 mg/kg and maximum of 125 mg/kg. The same type of vegetable from Mwembe, Same, contained a narrow range of 38.73 mg/kg to 47.5 mg/kg.

Ward [10] reported that the typical natural Mn concentrations of plants ranged from 20 to 240 mg/kg. Mills and Jones [7] reported ranges of 25 – 200 mg Mn/kg for spinach, 20 – 200 mg/kg for lettuce, and 25 – 150 mg/kg for broccoli. Based on these figures, most of the vegetables surveyed in the present study would supply tolerable levels of Mn for good human nutrition, although all of them are on the lower sides of the ranges cited.

TABLE 4: *Manganese contents (mg/kg) in different types of vegetable sampled from different areas*

Type of vegetable	Location sampled	n	Minimum content at location	Maximum content at location	Location mean	Standard error	Vegetable type mean
Pumpkin leaves	Uyole – Mbeya	3	126.26	158.82	141.08	9.51	
	Bigwa – Morogoro	3	32.81	45	37.81	3.68	89.45 abc
Amaranthus	Uyole – Mbeya	3	89.37	110	102.91	6.77	
	Mazimbu-Morogoro	3	31.25	35.62	32.91	1.36	
	Vumari – Same	3	67.5	101.25	84.16	9.74	73.33 abc
Black night shade	Uyole – Mbeya	3	91.25	150.61	118.12	17.36	
	Mazimbu-Morogoro	3	102.5	114.31	107.89	3.44	
	Mwembe- Same	3	38.73	47.5	42.08	2.73	89.37 abc
Chinesse cabbage	Uyole – Mbeya	3	102.5	124.84	113.67	6.45	
	Mazimbu-Morogoro	3	58.75	125	86.87	19.76	100.27 ab
Abyssinian mustard	Uyole – Mbeya	3	80.62	92.5	87.29	3.5	87.29 abc
Cassava leaves(rubber)	Kingulwira-Morogoro	3	55	57.5	56.45	0.75	56.46 bc
Cassava leaves(cassava)	Mazimbu-Morogoro	3	63.75	219.38	137.18	45.14	137.19 a
Sweetpotato leaves	Bigwa – Morogoro	3	51.25	116.87	93.33	21.09	
	Kisiwani – Same	3	98.75	110.62	104.2	3.49	
	Vumari – Same	3	52.5	75.62	60.41	7.6	85.99 abc
Egg plant	Mlali – Morogoro	3	13.12	17.5	15.2	1.26	15.21 c
Okra	Mikese – Morogoro	3	23.12	47.5	34.58	7.07	34.58 bc
African eggplant	Mgeta- Morogoro	3	11.87	34.37	22.29	6.54	22,29 c
Cowpea leaves	Mindu- Morogoro	3	55.62	113.43	85.31	16.7	85.31 abc
Jute	Mtombo-Morogoro	3	49.37	85.62	63.95	11.04	63.96 abc
Black jack	Mazimbu-Morogoro	3	43.75	67.37	54.37	7.71	54.38 bc

Means within vegetable type column followed by the same letter are not significantly different (P=0.05) according to the Turkey's test.

Iron contents in the vegetables

The iron contents of the vegetables are shown in Table 5.

TABLE 5: *Iron content (mg/kg) in different types of vegetables sampled from different areas*

Type of vegetable	Location sampled	n	Minimum content at location	Maximum content at location	Location mean	Standard error	Vegetable type mean
Pumpkin leaves	Uyole – Mbeya	3	512.5	626.57	553.65	36.56	
	Bigwa - Morogoro	3	187.5	362.5	300	56.36	426.83 ab
Amaranthus	Uyole – Mbeya	3	225	365.62	316.66	45.86	
	Mazimbu-Morogoro	3	425	531.25	472.91	31.11	
	Vumari – Same	3	318.75	409.37	362.5	26.2	384.03 abc
Black night shade	Uyole – Mbeya	3	340.62	521.87	425	52.69	
	Mazimbu-Morogoro	3	114.37	246.87	188.12	38.97	
	Mwembe- Same	3	140.62	203.12	181.25	20.33	264.79 abcd
Chinesse cabbage	Uyole – Mbeya	3	387.5	503.12	445.31	33.37	
	Mazimbu-Morogoro	3	350	607.75	510.91	81.01	478.11 a
Abyssinian mustard	Uyole – Mbeya	3	171.87	231.25	197.91	17.52	197.92 bcd
Cassava leaves(rubber)	Kingulwira-Morogoro	3	115.62	128.12	120.83	3.75	120.83 d
Cassava leaves(cassava)	Mazimbu-Morogoro	3	100	225	147.91	38.91	147.92 cd
Sweetpotato leaves	Bigwa - Morogoro	3	140.62	378.12	276.04	70.55	
	Kisiwani - Same	3	190.62	312.5	256.25	35.49	
	Vumari – Same	3	146.87	196.87	177.08	15.34	236.46 bcd
Egg plant	Mlali - Morogoro	3	90.62	125	105.2	10.25	105.21 d
Okra	Mikese - Morogoro	3	143.75	190.62	171.87	14.32	171.88 cd
African eggplant	Mgeta- Morogoro	3	57.37	128.12	102.08	21.52	102.08 d
Cowpea leaves	Mindu- Morogoro	3	175	206.25	187.5	9.54	187.5 cd
Jute	Mtombo- Morogoro	3	115.62	334.37	192.7	70.92	192.71 bcd
Black jack	Mazimbu-Morogoro	3	190.62	312.5	237.5	37.88	237.5 cd

Means within the vegetable type column followed by the same letter are not significantly different (P=0.05) according to the Tukey's test.

Generally, there were differences in Fe contents in different types of vegetables. The highest concentration of Fe obtained was from Chinese cabbage. The contents for all the vegetables sampled ranged from 102.08 mg/kg in African egg plant to 478.11 mg/kg in Chinese cabbage.

As for the other nutrients discussed above, the contents in a given type of vegetable seemed to differ with location. Cowpea leaves from Mindu, Morogoro, contained a minimum Fe content of 175 mg/kg and a maximum of 206.25 mg/kg, and the location mean concentrations for pumpkin leaves ranged from 300 to 553.65 mg/kg. The concentrations of Fe in different plants vis-a-vis the amounts rated as being nutritionally adequate may vary from location to location; however, the iron concentrations found in the present studies were above the Fe target level of 107.0 mg/kg, as rated by Welch and Bouis [12]. Some vegetables reported in the present studies, i.e. pumpkin leaves, amaranthus, black night shade, and Chinese cabbage, which contained Fe contents far above this target level, can be rated as being particularly good sources of Fe. Overall, the values reported in the present study give an indication that all the vegetables surveyed have nutritionally sufficient contents of Fe.

CONCLUSIONS

The concentrations of the different micronutrients in the vegetables studied showed differences with locations (a reflection of differences in soil fertility status that differs from one area to another), between vegetable types, and between different "varieties" of the same vegetable (as obtained from different localities). While the vegetables assessed herewith seem to provide quantities of Cu, Mn and Fe deemed sufficient to provide adequate nutrition, Zn was inferred as being in low supply in almost all vegetables. In the long term, more studies should be undertaken to systematically assess variations in nutrient contents across established varieties of vegetables in different soils/geographical locations. More local vegetables should be included, as there are many more different types of these than the ones reported herein that are popular in different locations of the country. The degree to which Zn contents of these vegetables could be improved by fertilization of low-Zn soils, or through choice of varieties (or local landraces) that have higher contents, should be explored.

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