Quantitation and correlation of selected nutrients in the soil, foliar, stem and root of edible weed, Talinum Paniculatum around University of KwaZulu-Natal, Pietermaritzburg, South Africa

George O. Achieng
Maseno University
Reinner Omondi (reinnerochola587@gmail.com)
University of Cape Town
Victor O. Shikuku
Kaimosi Friends University
George M. Okowa
CSI International Limited

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Abstract

The use of wild edible herbs as leafy vegetables is notably prevalent in South Africa, where they are commonly prepared as potherbs alongside cornmeal or incorporated into side dishes. However, *Talinum Paniculatum (T. Paniculatum)*, a wild edible herb, remains relatively obscure and underappreciated compared to introduced non-native vegetables. It needs increased attention, given its status as a ubiquitous weed and its potential to meet daily human nutritional needs. This study aimed to assess the nutrient content in the soil, foliage, stem, and roots of the edible weed *T. Paniculatum* in the vicinity of the University of KwaZulu-Natal, Pietermaritzburg, South Africa. Additionally, the study sought to establish correlations between nutrient levels in foliar and soil samples. Triplicates of plant matter and soil samples were collected from campus, roadside, and riverside sites, carefully prepared, and analyzed following the standardized protocols. Results were compared against FAO/WHO standard limits to determine compliance status. Notably, compliant levels of Fe, Cu, Zn, and Na were observed in the foliar samples across all three sampling sites. However, levels of Ca and K fell within tolerable limits only in campus and riverside samples, respectively. It is noteworthy, that the foliar samples exhibited an average gross calorific value of 0.6561 kcal/g. Conversely, levels of Mn, Mg, and Pb exceeded permissible limits as stipulated by standards. Soil analysis revealed that pH, Fe, Cu (except in campus samples), Mn, Zn, and Pb were within permissible limits. Nevertheless, concentrations of Ca, Na, Mg, and K surpassed tolerable levels. This comprehensive examination sheds light on the nutritional potential of *T. Paniculatum*, emphasizing the importance of recognizing and harnessing the benefits of this underutilized wild edible herb.

1. Introduction

Since ancient times, weeds have held significant roles in traditional cultures, serving diverse purposes such as medicinal applications, food sources, magical practices, goods production, and participation in religious rituals.[1–4] In Africa and various other developing regions, edible weeds have been closely linked to periods of famine, earning them the moniker "famine food."[5] These resilient plants play a crucial role in addressing dietary needs, overcoming food shortages, and contributing to income generation [1, 6, 7]. The prominence of wild edible herbs as leafy vegetables is particularly evident in South Africa, where over 100 species of these plants are utilized, either cooked as potherbs with cornmeal (*Zea mays*) or incorporated into side dishes. [8–14] Despite the increasing acknowledgement of the vital role played by edible wild plants in both rural and urban livelihoods in South Africa, there remains a paucity of information regarding their safety and nutritional composition. It is within this context that we endeavor to present a preliminary assessment of the nutritive value of *T. Paniculatum* collected around the University of KwaZulu-Natal, Pietermaritzburg, South Africa. This assessment aims to determine the nutrient content and identify potentially unhealthy contaminants, with a particular focus on heavy metals. It is noteworthy that *T. Paniculatum* is relatively unknown and underutilized in South Africa in comparison to introduced non-native vegetables. However, our study posits that this common weed merits increased attention due to its potential to meet daily human nutritional requirements. As we delve into the nutritive aspects of *T. Paniculatum*, we hope to shed light on its significance and encourage a reevaluation of its role in the local diet and agricultural practices.

1.1 Brief overview of T. Paniculatum

T. paniculatum, commonly known as fame flower or Jewels-of-Opar, originates from Latin America, the southern United States, and the Caribbean.[15, 16] Morphologically, *T. paniculatum* is a fleshy, glabrous herbaceous perennial that can reach heights of 100–120 cm (Fig. 1.1). Thriving in well-drained and moist soil rich in organic matter, the plant prefers full sun but exhibits remarkable shade and drought tolerance. Noteworthy for its versatility, the plant is often harvested from the wild for its edible leaves, which are locally consumed. [17, 18] In traditional folk medicine, *T. paniculatum* is employed to address various ailments, including gastrointestinal problems, pneumonia, cancer, skin infections, headaches, and reproductive disorders. [19, 20] These medicinal properties are attributed to the plant's high concentrations of phytosterols, encompassing flavonoids and alkaloid [21]. The succulent leaves and shoots are used in green salads in tropical America, and soups and stews, in Nigeria, Ghana, and DR Congo [19]. Beyond its medicinal applications, the succulent leaves, and shoots of *T. paniculatum* contribute to culinary practices. In tropical America, they are incorporated into green salads, while in Nigeria, Ghana, and Democratic Republic of Congo; they find use in soups and stews.

2. Materials and methods

2.1 Area of study

The field studies were performed in three areas around the University of KwaZulu-Natal, Pietermaritzburg, South Africa. The study areas were, on campus site (S 29°37'6.13243 latitude, E 30°23'43.68242 longitude); roadside location (S 29°37'7.69998 latitude, E 30°23'38.97978 longitude); riverside site (S 29°36'52.49243 latitude, E 30°23'26.81664 longitude). The study area receives most rainfall during the month of January, 112 mm (mid-summer), and the lowest in July, 6 mm (winter). [22] The subsistence economy of the area rests mainly on maize (corn) cultivation and cattle raising. The city is predominantly occupied by the black-Africans (Zulu people), making up 70% of the population, whereas whites, Indians, and coloreds, account for 14.2, 8.4, and 6.9%, respectively [23]. Wild vegetables are widely available in Pietermaritzburg and are inexpensive for low-income earners. For instance, among the Zulu, edible wild herbs such as *Colocasia esculenta*, *Momordica foetida*, and *Amaranthus hybridus*, are gathered from agricultural fields and sold at road markets by women [24]. The geographical location of the study site, indicating the geographical position of Pietermaritzburg is given in Fig. 2.1.

2.2 Plant material

The *T. paniculatum* leaves were collected in the morning of 15, November 2019. The botanical identification of the plant was conducted using pharmaco-botanical methods. A sample of the plant was identified and stored in the Herbarium at the University of KwaZulu-Natal, Pietermaritzburg campus, under the specimen number NU 0086062.

2.3 Sampling of plant materials and soil, preparation, and analysis

The sampling locations namely, campus, roadside and riverside sites were arrived at based on large population of the edible weed, *T. paniculatum* in these areas. The plants were carefully uprooted, put into sampling bags, labelled appropriately, and taken to the laboratory. The plants were separated into foliar, stem and root then dried in Hot Air Oven for 12 h at 70 ^{o}C. The samples were crushed, and ground appropriately then sieved using a 2 mm sieve. A weight of 0.5 g for each sample was put into labelled conical flasks in a fume hood and 10 mL of 69% HNO_3 and 2 mL H_2O_2 added. The mixtures were digested on a hotplate to almost dryness, cooled and transferred quantitatively into 250 mL volumetric flask. The resulting solutions were transferred into labelled test-tubes and run on an Atomic Absorption Spectrophotometer. The final elemental levels were obtained by multiplying the machine reading by (250/0.5).

From a depth of 0–30 cm, 1 kg soil samples from each location were taken using stainless-steel soil auger, well labelled and taken to the laboratory. The samples were cleaned of plant and other debris, dried in a Hot Air Oven at 700 ^{o}C for 12 h, ground to break the larger soil particles and sieved using a 2 mm Sieve. Five (5) grams of the soil were weighed into a labelled 50 mL PTFE bottle and shaken on the shaker for 1 h at 180 rpm, then analyzed for pH levels. For trace elements (Fe, Zn, Pb and Cu) 50 mL of 0.1N HCl was added, while for available elements (Mn, Mg, Na, K, Ca, and Zn), 25 mL of the digestion mixture (0.03 N H_2SO_4 and 0.1 N HCl) was added. The samples were filtered into 250 mL conical flasks, topped up to the mark using deionized water and transferred into a test tube and run on Atomic Absorption Spectrophotometer. All dilution factors were computed prior to multiplying with the initial dilution factors. Machine readings were multiplied by (25/5) and (50/5) for available and trace elements, respectively.

2.4 Quality control and assurance

The existing standard procedures and protocols were adhered to during analysis of foliar, stem and soil samples. Precisely, the samples, certified reference materials for soil and vegetable puree were treated in a similar manner during sample preparation prior to instrumental analysis. In addition, proficiency testing (PT), duplicate, blank, retained, and second standard samples were analyzed. For the standard curves generated, the ones exhibiting r^2 values greater than 0.995 were adopted for reading out the concentrations of the elements in the samples.

2.5 Data analysis

Microsoft office excel was used to arrange the data and significant differences at 95% confidence ($P \leq 0.05$) level were obtained using the Statistical Analysis Software (SAS System for Windows Version 8). Correlation Pearson r was determined using Graph-Pad Prism 9.4.0 (673).

3. Results and discussion

3.1 Elemental composition in plant tissues

The results of elemental composition in the stem, roots and foliar of *T. Paniculatum* are given in Table 3.1a. The average concentrations of the metals varied significantly within the sample type and the locations. Campus sites recorded the highest concentrations of Ca, K and Mg in the stem, roots and foliar, respectively. At the Roadside location, Mg, K and Ca afforded the highest concentrations in the stem, roots and foliar, respectively.

Table 3.1

a: Elemental composition in stem, roots and foliar of edible weed

Location	**Sample**	**Element (mg/kg)**								
		Fe	**Cu**	**Mn**	**Zn**	**Pb**	**Ca**	**Na**	**Mg**	**K**
Campus	Stem	78.88^f	0.99^e	13.27^h	8.37^e	0.95^f	3732.17^a	11.67^h	1102.84^b	1918.64^d
	Roots	0.747^h	0.78^f	59.92^d	8.06^e	0.79^g	1235.00^e	33.78^f	506.16^g	2141.29^b
	Foliar	30.13^g	0.50^g	3.48^i	7.77^e	0.96^f	732.00^g	37.45^e	868.15^c	734.63^h
Roadside	Stem	214.00^b	0.48^h	23.43^g	9.93^d	1.13^e	552.15^h	0.48^i	754.65^e	763.98^g
	Roots	304.37^a	1.02^d	65.77^c	10.07^d	2.65^b	560.00^h	55.67^b	752.25^e	2728.28^a
	Foliar	192.67^c	1.39^a	111.00^a	16.23^c	3.09^a	2001.33^c	74.33^a	1271.12^a	1684.65^e
Riverside	Stem	187.67^d	1.17^c	40.87^e	18.90^b	1.21^d	1390.00^d	24.10^g	425.90^h	2047.58^c
	Roots	1.85^h	0.98^e	66.94^b	6.19^f	1.19^d	796.77^f	44.02^c	759.97^d	1002.28^f
	Foliar	127.33^e	1.22^b	30.14^f	23.95^a	1.52^c	2190.00^b	41.23^d	711.17^f	454.19^i
	CV%	1.30	0.93	0.81	3.78	0.84	0.91	1.05	0.19	0.96
LSD, $P \leq 0.05$		2.83	0.015	0.64	0.79	0.02	22.98	0.65	2.64	24.69
^{a,b,c,d,e,f,g,h,i} signify Least Significance Differences (LSD, $p \leq 0.05$); CV%-Percent Coefficient of Variation										

The data on elemental levels at the Riverside indicated that K was the most dominant element in both the stem and roots. On the other hand, Ca level was the highest in the foliar. Khattak et al.[25] examined weeds, frequently used as vegetables, for their mineral composition. Two leafy weeds, Amarnath (*Amaranthus dubius*) and wild onion (*Brodiaea capitata*), consumed as non-conventional vegetables, were investigated for selected mineral composition in which they exhibited different levels of minerals. Amarnath registered the highest Fe concentration (342.0 mg/kg) followed by wild onion leaves (69.0 mg/kg). On the other hand, amarnath recorded Ca, Mg, Mn, Cu, and Zn concentrations of 7212.0, 8125.0, 38.0, 11.0, and 43.0 mg/kg, correspondingly. In addition, the concentrations of the minerals were 455.0, 1547.0, 5.6, 6.8, and 29.8, mg/kg, respectively, in wild onion foliar. The results obtained by Karahan et al. [26] on seventeen medicinal plants showed that plants grown in regions with heavy traffic congestion present significantly higher heavy metal levels compared to normal levels. Precisely, the measured values for concentrations from lowest to highest were (in mg/kg), 1335.699-11213.951 for Ca, 23.838–90.444 for Cu, 78.960-1228.845 for Fe, 1035.948-6393.491 for K, 83.193-2252.031 for Mg, 12.111–362.570 for Mn, 278.464-1968.775 for Na, 0.796–17.162 for Pb and 166.910-395.252 for Zn. Comparison analysis of heavy metal concentration in urban and rural crops with focus on surface deposition and tissue accumulation of pollutants was explored. [27] The results demonstrated that in the city, crops near the road were polluted by heavy metals, with up to 160 mg/kg of dry weight for lettuce and 210 mg/kg for basil. The concentrations of Copper (Cu), lead (Pb) and zinc (Zn) in cucumber, tomato, green pepper, lettuce, parsley, onion, bean, eggplant, peppermint, pumpkin, and okra produced in Kayseri, Turkey, were evaluated. [28] The order of the elements in various vegetables and their concentration ranges in mg/kg were Cu (22.19–76.5), Pb (3–10.7) and Zn (3.56–259.2). The concentrations of Cu and Zn in vegetables studied were within the recommended international standards. The results also showed that onion and peppermint accumulated more Cu than the other vegetables studied. Moreover, there were statistically significant differences ($p \leq 0.05$) between the levels of Zn and Pb in all the vegetables analyzed from urban and rural areas. The concentrations of heavy metals in the vegetables in this study were generally lower than the soil samples. These results are attributed to the root, which seems to act as a barrier to the translocation of metals. [29] Yahaya [30] evaluated the levels of Lead (Pb), Iron (Fe), Zinc (Zn) and Copper (Cu) in four different samples of vegetables purchased from the local market. The researcher reported that the relative abundance of metals in vegetables followed the sequence Cu (0.483 mg/kg) > Zn (0.268 mg/kg) > Fe (0.260 mg/kg) > Pb (0.095 mg/kg). This trend is not in agreement with the one observed in the current study which followed the sequence Fe (30.13 mg/kg) > Zn (7.77 mg/kg) > Pb (0.96 mg/kg) > Cu (0.50 mg/kg) for the foliar sample within the Campus site. Owing to the fact that wild edible herbs are used as leafy vegetables of which *T. paniculatum* is part, the foliar elemental concentrations were evaluated against the FAO/WHO permissible limits (Table 3.1b) in order to establish their compliance status for consumption safety. Compliant levels of Fe, Cu, Zn, and Na in the foliar samples were recorded in all the three sampling sites. However, the levels of Ca and K were within tolerable limits in campus and riverside samples, respectively. Contrary, the levels of Mn, Mg, and Pb surpassed the permissible confines prescribed in the standards.

Table 3.1
b: FAO/WHO permissible limits for foliar elemental concentrations

	Parameters (mg/kg)								
	Fe	**Cu**	**Mn**	**Zn**	**Pb**	**Ca**	**Na**	**Mg**	**K**
Limits	425.5	73.3	0.2	99.4	0.3	800–1000	200–250	375–400	470–490

3.2 Elemental composition in soil samples

Soil elemental data (Table 3.2a) showed that the metal concentrations were significantly different. To be precise, the concentration of Ca was the highest at the Campus and Riverside while Mg was dominant at the Roadside. In addition, soil pH was also analyzed in which the levels at the three locations ranged between 6.65 to 7.22, implying that the soil samples were relatively neutral.

Table 3.2
a: Soil pH and metal composition (mg/kg)

	Parameters									
Location	**pH**	**Fe**	**Cu**	**Mn**	**Zn**	**Pb**	**Ca**	**Na**	**Mg**	**K**
Campus	7.22[a]	2113.33[a]	104.71[a]	37.99[c]	12.84[c]	5.11[b]	7270.65[a]	152.41[a]	1181.75[b]	878.67[a]
Roadside	6.77[b]	1267.42[b]	9.58[b]	54.75[b]	18.87[a]	5.16[b]	1340.96[b]	140.18[b]	1551.81[a]	104.58[c]
Riverside	6.65[c]	34.29[c]	9.96[b]	273.43[a]	14.48[b]	20.28[a]	857.31[c]	117.86[c]	319.10[c]	159.59[b]
CV%	0.26	2.19	78.86	3.02	0.77	2.28	0.52	0.64	0.16	0.31
LSD, P ≤ 0.05	0.04	56.48	74.04	8.37	0.27	0.53	37.15	1.98	3.64	2.65

[a,b,c] signify Least Significance Differences (LSD, p ≤ 0.05); CV%-Percent Coefficient of Variation

The levels of the parameters were compared with FAO/WHO permissible limits in soil (Table 2b). The results showed that pH, Fe, Cu (except in Campus samples), Mn, Zn and Pb were within permissible limits. However, the levels of Ca, Na, Mg and K surpassed the tolerable concentrations.

Table 3.2
b: FAO/WHO permissible limits for pH level and metal concentrations

	Parameters									
	pH	**Fe**	**Cu**	**Mn**	**Zn**	**Pb**	**Ca**	**Na**	**Mg**	**K**
Limits	6.5–7.5	5%	36	437	50	85	430–540	40	40–50	40–80

N/B: The concentrations of the other metals are in mg/kg

3.3 Correlation of elemental concentrations in soil and foliar matrices

Pearson Correlation *r* of elemental concentrations in soil and foliar is given in Table 3.3.

Table 3.3
Pearson correlation coefficient values

Location	**Element**								
	Fe	**Mg**	**Pb**	**Na**	**K**	**Cu**	**Mn**	**Ca**	**Zn**
Roadside	-0.9538	0.992	0.327	0.866	-0.263	0.000	-0.500	0.292	-0.788
Riverside	0.0000	0.040	1.000	0.596	-0.712	0.866	-0.663	-0.999	0.982
Campus	0.052	-1.000	1.000	-0.113	-0.830	-0.491	-0.198	0.491	-0.403

High negative correlation was recorded for Fe at the Roadside, very low correlation at the Campus, and no correlation at the Riverside. With respect to Mg levels, high positive, high negative and no correlations were witnessed at the Roadside, Campus, and Riverside, respectively. The concentrations of Pb highly correlated at the Riverside and Campus sites with very low correlation at the Roadside. High positive correlation of Na was recorded in the samples from the Riverside and Roadside while low negative correlation at the Campus. Low negative correlation for K levels was observed at the Roadside, while high negative correlation was posted at the Campus and Riverside. There was no correlation for Zn levels at the Roadside, high positive correlation at the Riverside and negative correlation at the Campus. Conversely, negative correlations for Mn concentrations were recorded at three sampling points. In addition, the Roadside and Campus were characterized by low positive correlation for Ca and high negative correlation at the Riverside. Lastly, negative correlation at the Roadside and Campus, and high positive correlation were recorded at the Riverside for Cu levels. Hao et al. [31] observed inconsistent results concerning the correlations between leaf elements and environmental factors, thus, emphasizing the need to explore the influence of soil and climatic conditions on leaf element concentrations. The relationship between multi-element composition in tea leaves and in provenance soils for geographical traceability was studied and established that the accumulation of some elements in tea-leaves was closely correlated with their concentrations in soils. [32]

3.4 Quality control during analysis

Quality control is a tradition carried out during sample analysis to verify and improve the quality of the results reported. In this study, quality control data were achieved by analyzing certified reference material (CRM) for soil, vegetable puree for plant foliar and root samples, and plotting trend curves from the proficiency testing (PT) scheme for the enumerated parameters in this research. The results are summarized in Appendices 1, 2 and 3, where it can be concluded that quantification of metal concentrations in soil, stem, roots and foliar, and pH in the soil from the considered locations were done with utmost precision, since the results recorded were within the limits.

3.5 Suitability of *Talinum Paniculatum* leaves for consumption as vegetable

The findings of this study show that the foliar of the edible weed (*T. paniculatum*) is rich in micronutrients (Table 3.1a) and calories (gross calorific value of 0.6561 kcal/g). Wild vegetables are readily and freely accessible and their importance as sources of cheaper mineral cannot be overlooked. [33] Calcium is necessary for bone and skeletal development and iron is essential for hemoglobin formation while the other minerals perform a variety of physical and physiological functions. van Rensburg et al.[34] reported that leaves of nightshade, pigweed and spider flower provided Fe, Mg, and energy in the diet. Research by Cruz-Garcia & Price [33] showed that wild vegetables (weeds) scored the highest Cognitive Salience Index (CSI) supporting the affirmation that weeds are culturally and cognitively important as a vegetable source. In another study, nutritional values of *Amaranthus, Cleome, Solanum and Corchorus* consumed as vegetables were evaluated and ascertained to be good sources of minerals, particularly Ca and Fe.[34] Although Fe and Ca from plant sources are insufficient since they are poorly absorbed, it should be understood that if the plants are combined with some food from animal source, the efficiency of mineral absorption could be enhanced. Maroyi [35] reported that rural households engage in harvesting of wild edible vegetables and other non-timber forest products (NTFPs) as a survival strategy. The researcher concluded that based on the potential nutritional and medicinal value of edible weeds, they could contribute in a major way to food security, basic primary health care and balanced diets of both urban and rural households. Yahaya [30] noted that the levels of Pb, Zn and Cu metals in selected green leafy vegetables were compliant with the FAO/WHO recommended levels. According to the researcher, this observation, especially low concentrations of Pb, in all the samples are indications that these plants contribute less toxic effects of metals, thus, qualifying the vegetables as the potential sources of essential trace elements.

4. Conclusions

Average concentrations of the metals varied significantly within the sample type and the locations. Foliar of the edible weed (*T. paniculatum*) is rich in micronutrients and calories (gross calorific value of 0.6561 kcal/g). Soil pH levels at the three locations were in the range 6.65–7.22 inferring the neutral nature of the soil. Pearson Correlation r of elemental concentrations in soil and foliar was characterized by intermittent trend. The foliar data obtained in this research showed the nutritional potential of *T. Paniculatum*, thus, emphasizing the importance of recognizing and harnessing the benefits of this underutilized wild edible herb.

Declarations

Authorship Contribution Statement

George O. Achieng': Conceptualisation, Investigation, Data Curation, Writing-Original Draft, Validation, Formal Analysis. **Reinner O. Omondi:** Conceptualisation, Investigation, Project Administration, Writing-Review and Editing. **Victor O. Shikuku:** Writing-Review and Editing. **George M. Okowa:** Investigation, and Data Curation.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

Figure 1

Figure 1.1: *T. Paniculatum,* on campus plants

Figure 2

Figure 2.1: Geographical location of the study site indicating the sampling positions at Pietermaritzburg

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