# The contribution of indigenous vegetables to food security and nutrition within selected sites in South Africa

By

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# DECLARATION

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## ABSTRACT

South Africa is rich in biodiversity among which are semi-domesticated vegetable species which are known as wild or indigenous vegetables. These wild indigenous vegetables have been reported to be good in nutritional qualities such as macro and micronutrients. However, there is still a high prevalence of malnutrition; especially micronutrient deficiencies among low or marginal income bracket of the population. The use of indigenous vegetables has been proposed as part of the solutions to the problems of micronutrient malnutrition among these populations. Indigenous vegetables are an important source of food in the maize based subsistence farming sector of rural South Africa. Their main role is as relish as they are used as an accompaniment for staple cereal based diets. They are also generally reported to be rich in micronutrients. Although they may be consumed in small quantities, they influence the intake of cereal staples, manage hunger and play a central role in household food security for the poorer rural groups. Mixing several indigenous vegetables species in one meal contributes to dietary diversity in terms of more vegetable types as well as in terms of choice of relish. For some very poor families indigenous vegetables are substitutes for some food crops. The seasonal occurrence of these vegetables leaves many families without a food source during the off-season. Indigenous vegetables increase agro-biodiversity at the household level. This agro-biodiversity helps in buffering against the accumulation and multiplication of pests and diseases and provides important cover for the soil. Further research on agronomic, social and economic dimensions is required to understand the roles of IV in subsistence farming systems in South Africa.

The survey study revealed that indigenous vegetables were important in the diets of most rural people in the study area. They were consumed as relish although they were not being cultivated. Their method of acquisition was gathering from homesteads and the wild. These vegetables were also believed to be medicinal. The local naming of wild vegetables varied among villages in the same district such that a vegetable in one village was assigned to a different species of vegetable in another village. They were reportedly abundant during summer and there was a decrease in availability off-season leaving vulnerable people who rely on them with a food

shortage. The utilisation of wild vegetables among South Africans is reported to be declining due to over reliance on introduced temperate species.

Efforts to domesticate and cultivate wild vegetables could be hampered by several factors including seed dormancy and premature flowering. In this present study dormancy was observed in *C. olitorius*. The response of wild genotypes *of C. olitorius* with different seed sizes to various dry heat and hot water treatments was evaluated. Steeping seeds in boiling water (95°C) for ten seconds and soaking seeds in a hot water bath at 80°C for ten minutes resulted in the highest response to germination in this species. The study also recorded significant interactions between heat treatment and seed sizes. We concluded that C. *olitorius* seeds of different sizes require diverse durations of exposure to heat treatment methods to break dormancy caused by an impermeable seed coat. *Cleome gynandra* is another species that is consumed as a vegetable in various parts of the world including Africa. The plant is also used as a medicinal herb for the treatment of various human diseases. Among the wild vegetables, *C. gynandra* has been reported to flower prematurely, a phenomenon known as bolting and common in many vegetable crops. Premature flowering (bolting) can be as a response to temperature extremes and photoperiod and affects many other leafy vegetables such as lettuce (*Lactuca sativa*), spinach (*Spinacea oleracea*) and mustard rape (*Brassica juncea)*. Bolting leads to production losses in leaf vegetable crops as they flower before they have produced an economic yield. The removal of flowers and nitrogen application resulted in significant increases in the fresh and dry weight of cleome leaves. Removal of flowers resulted in a 46% increase in fresh weight of leaves. The observed positive response of leaf yield to removal of flowers offers a possible way to deal with the problem of bolting. The continuous removal of the flowers leads to increased utilisable leaf yield. The application of incremental amounts of nitrogen top dressing results in increased leaf yield in C. *gynandra.*

The response of selected indigenous vegetables (*Corchorus olitorius* and *Amaranthus cruentus*) to micronutrients added to the soil was compared with the response of a reference crop; Swiss chard (*Beta vulgaris* var. cicla). For all the levels of micronutrients applied, Swiss chard accumulated Cu, Zn and Mn in the leaves at significantly ($p<0.01$) higher concentrations than the wild vegetables. Variations

between the vegetables in the micronutrients were greater for Zn (72–363 ppm) and Mn (97.9–285.9 ppm) for Cu (8.8–14 ppm). *C. olitorius* had the least capacity to concentrate Mn and Zn in the leaf, which suggested that this vegetable is a less attractive candidate for agronomic bio-fortification of these elements. However, *C. olitorius* accumulated Fe at a significantly higher concentration (327 ppm) in the leaves than did *Amaranthus* (222 ppm) or Swiss chard (295 ppm). Sulphur as a macronutrient varied little in the plant species tested. The mean S concentration in the leaves ranged from 0.26% in *C. olitorius* to 0.34% in *Amaranthus cruentus* and Swiss chard. We concluded that the different vegetables have different abilities to take up Cu and Zn in the order Swiss chard > *Amaranthus* > *Corchorus*, and that they responded to micronutrients added to the soil but only up to certain limits of supplementation. The results from this current study seem to contradict the belief that wild vegetables have the inherent ability to concentrate mineral micronutrients in their tissue.

Factors such as environment, anti-nutrients, dietary diversity, plant parts, plant age, and varieties result in differences in reported nutritional composition of indigenous vegetables. Post-harvest handling, storage, cooking and preservation also alter the composition. The need to optimise protocols for each vegetable type and for different laboratories makes analysis expensive. Equipment and methods of analysis are varied and may not be comparable, making it difficult to generalise on the composition of these vegetables. The Agricultural Research Council of South Africa and other stake holders are conducting studies on some aspects of these vegetables. There are still many information gaps regarding many aspects of these vegetables which require research attention. These include; the selection and improvement of genotypes, seed biology and germination studies, agronomic (population, fertiliser, crop mixtures) studies and phyto-chemical evaluation of these important species in order to encourage the overall use of these important indigenous resources. Finally, there is need to promote their increased utilisation.

**Keywords:**

Household food security, indigenous vegetables, wild vegetables, maize, staple diet, subsistence farming system, poverty, nutrition, micronutrients, South Africa.

## OPSOMMING

Suid- Afrika is ryk aan biodiversiteit waaronder half-mak groente spesies, wat as wilde of inheemse groente bekend is, voorkom. Hierdie wilde inheemse groente is aangedui om goed in voedingswaarde te wees met voldoende makro-en mikrovoedingstowwe. Daar is egter nogsteeds 'n hoë voorkoms van wanvoeding, veral tekorte aan mikronutriënte onder die lae of marginale inkomstegroep van die bevolking. Die gebruik van inheemse groente word voorgestel as deel van die oplossing van die probleem van wanvoeding onder hierdie bevolkings. Inheemse groente is 'n belangrike bron van voedsel in die mielie gebaseerde bestaansboerdery sektor van landelike Suid-Afrika. Hul vernaamste rol is as smoor waar dit gebruik word tesame met stapelvoedsel in ŉ graan-gebaseerde dieet. Hierdie groentes was oor die algemeen ook aangedui om ryk te wees in mikrovoedingstowwe. Hoewel hulle verteer kan word in klein hoeveelhede, beïnvloed hulle die inname van graan stapelvoedsel, en speel 'n sentrale rol in huishoudelike voedselsekuriteit vir die armer landelike groepe. Vermenging van verskeie inheemse groente spesies in een maaltyd dra by tot die dieet diversiteit in terme van meer groentesoorte sowel as in terme van die keuse van smaak. Vir 'n paar baie arm gesinne is inheemse groentes die plaasvervanger vir gewone groente gewasse. Die seisoenale voorkoms van hierdie groente laat baie gesinne sonder 'n bron van voedsel gedurende die af-seisoen. Inheemse groente verhoog landbou-biodiversiteit op ŉ huishoudelike vlak . Hierdie landbou-biodiversiteit help buffer teen die opbou en vermeerdering van peste en siektes en bied belangrike dekking vir die grond. Verdere navorsing op akkerbou-, maatskaplike en ekonomiese aspekte is nodig om die rolle van inheemse groentes in bestaansboerdery in Suid-Afrika te verstaan.

Die studie opname het getoon dat inheemse groente belangrik was in die dieet van die meeste mense van die platteland in die studie area. Hierdie groentes was gebruik as smoor hoewel hulle nie gekweek word nie. Hul metode van verkryging is deur dit te versamel van huise en die natuur. Die groentes word ook as medisinaal beskou. Die plaaslike benaming van wilde groente het gewissel tussen dorpe in dieselfde distrik, tot so 'n mate dat die benaming van groente tussen dorpe verskil. Hulle was na bewering volop in die somer, en daar was 'n afname in die

beskikbaarheid af-seisoen, wat kwesbare mense, wat staatmaak op hul voorkoms, met 'n tekort aan kos laat. Die benutting van wilde groente onder Suid-Afrikaners daal as gevolg van die afhanklikheid in nuwe spsies.

Pogings om te mak en wilde groente te kweek, kan belemmer word deur verskeie faktore, insluitend saaddormansie en voortydige blom. In hierdie studie was dormansie waargeneem in *C. olitorius*. Die reaksie van wilde genotipes van C. *olitorius* met verskillende saad groottes op verskeie droë hitte en warm water behandelings, was geëvalueer. Sade was geweek in kookwater ( 95$^{o}$C ) vir tien sekondes en ander in 'n warm water bad by 80$^{o}$C vir tien minute, en het gelei tot die hoogste reaksie op ontkieming in hierdie spesie. Die studie het ook belangrike interaksies tussen hitte behandeling en saad groottes getoon. Ons het tot die gevolgtrekking gekom dat C. *olitorius* sade van verskillende groottes diverse duur van blootstelling vereis en ook so m.b.t. die ondeurdringbare saadhuid. *Cleome gynandra* is nog 'n spesie wat as 'n groente in verskeie dele van die wêreld, insluitend Afrika verbruik word. Die plant word ook gebruik as 'n medisinale plant vir die behandeling van verskeie siektes van die mens. Onder die wilde groente, was C. *gynandra* aangedui om vroeg te blom, 'n verskynsel wat bekend staan as “bolting” en is algemeen in baie groente gewasse. Voortydige blom (vas) kan wees as 'n reaksie op die temperatuur uiterstes en fotoperiode en raak ook baie ander groen groente soos blaarslaai (*Lactuca sativa*) , spinasie (*Spinacea oleracea*) en mosterd (*Brassica juncea* ) . “Bolting” lei ook tot produksie verliese in blaar groentegewasse as hulle blom voordat hulle 'n ekonomiese opbrengs opgelewer het. Die verwydering van blomme en stikstof toediening het gelei tot 'n aansienlike toename in die vars en droë gewig van Cleome blare. Verwydering van blomme het gelei tot 'n toename van 46% in vars gewig van die blare. Die waargenome positiewe reaksie van die blaar opbrengs deur verwydering van blomme bied 'n moontlike manier om die “bolting” probleem te hanteer. Die voortdurende verwydering van die blomme lei tot verhoogde bruikbare blaar opbrengs. Die toepassing van toenemende stikstof topbemesting het verhoogde blaar opbrengs in C. gynandra tot gevolg.

Die reaksie van geselekteerde inheemse groente (*Corchorus olitorius* en *Amaranthus* spp ) met mikrovoedingstowwe toegevoeg tot die grond, is in vergelyk met die reaksie van 'n verwysings gewas; spinasiebeet (*Beta vulgaris* var cicla . ). Vir al die vlakke van mikronutriente toegepas, was die spinasiebeet opgehoopte Cu , Zn en Mn in die blare, in beduidend ($p < 0.01$ ) hoër konsentrasies as die wilde groente.

Variasies tussen die groente se mikrovoedingstowwe was groter vir Zn (72–363 dpm) en Mn (97.9–285.9 dpm) vir Cu (8.8–14 dpm). C. *olitorius* het die laagste kapasiteit om Mn en Zn in die blaar te konsentreer, wat veroorsaak dat hierdie groente is 'n minder aantreklike kandidaat vir akkerbou bio-fortifikasie van hierdie elemente. Maar, C. *olitorius* het aansienlik hoër opgehoopte Fe konsentrasie (327 dpm) in die blare as Amaranthus (222 dpm) en spinasiebeet (295 dpm). Sulphur as 'n macronutrient varieer bietjie in die plant spesies wat getoets. Die gemiddelde S konsentrasie in die blare het gewissel van 0.26% in C. olitorius tot 0.34% in *Amaranthus* spp en spinasiebeet. Ons het tot die gevolgtrekking gekom dat die verskillende groente oor verskillende vermoëns beskik om Cu en Zn op te neem, en wel in die orde spinasiebeet > *Amaranthus* > *Corchorus*, en dat hulle wel gereageer het op mikro aanvullings in die grond, maar net tot sekere perke van die aanvulling . Die resultate van die huidige studie blyk dat die oortuiging wat bestaan dat die wilde groente die inherente vermoë het om minerale mikro te konsentreer in hul weefsel, weerspreek word.

Faktore soos die omgewing , anti - voedingstowwe , dieet diversiteit , dele van plante , plant ouderdom, en variëteite veroorsaak verskille in voedingsamestelling van inheemse groente. Na-oes hantering, berging, kook en bewaring, veroorsaak ook verandering in die samestelling. Die behoefte protokolle vir elke groente tipe, en om dit vir verskillende laboratoriums te optimaliseer, maak ontleding duur. Toerusting en metodes van ontleding verskil baie, en kan nie vergelyk word nie, wat dit moeilik maak om te veralgemeen oor die samestelling van hierdie groente. Die Landbou Navorsingsraad van Suid-Afrika en ander belanghebbendes is besig met studies op 'n paar aspekte van hierdie groente. Daar is nog baie gapings in inligting oor verskeie aspekte van hierdie groente wat navorsing vereis. Dit sluit in: die seleksie en die verbetering van genotipes, saad, biologie en ontkieming studies, agronomiese (bevolking, kunsmis, oes mengsels ) studies en fito -chemiese evaluering van hierdie belangrike spesies ten einde die algehele gebruik van hierdie belangrike inheemse hulpbronne aan te moedig. Ten slotte, is daar nodig het om hul verhoogde gebruik te bevorder.

# DEDICATION

**To all who work to feed the world**

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| | |
|---|---|
| AA: | Atomic absorption |
| ANOVA: | analysis of variance |
| ARC-VOPI: | Agricultural Research Council – Vegetable and Ornamental Plant Institute |
| ARVs: | Anti-retrovirals |
| Ca: | calcium |
| CDB: | Convention on Biodiversity |
| CEC: | Cation exchange capacity |
| cmol: | centimoles |
| CRD: | completely randomised design |
| d.f: | degrees of freedom |
| DAS: | days after sowing |
| DMRT: | Duncan’s multiple range test |
| DNA: | deoxyribonucleic acid |
| FAO: | Food and Agriculture Organisation |
| Fe: | iron |
| FEWSNET: | Famine Early Warning Network |
| FSSA: | Fertiliser Society of South Africa |
| g: | gram |
| GDP: | Gross Domestic Product |
| ha: | hectare |
| INRA: | Institute for Natural Resources Africa |
| kcal: | kilocalories |
| kg: | kilogramme |
| KZN: | KwaZulu-Natal |
| L: | liter |
| LAN: | lime(stone) ammonium nitrate |
| Lsd: | least significant difference |
| M.S: | mean square |
| Mg: | magnesium |
| mg: | milligram |
| ml: | millilitre |

| | |
|---|---|
| Mn: | manganese |
| N: | nitrogen |
| NDA: | National Department of Agriculture |
| NFCS: | National Food Consumption Survey |
| NPK: | Nitrogen: Phosphorus: Potassium |
| PGRU: | Plant Genetic Resources Unit |
| ppm: | parts per million |
| R: | rands |
| RCBD: | Randomised complete block design |
| S.S: | sum of squares |
| S: | sulphur |
| SASRI: | South African Sugar Research Institute |
| SH: | smallholder |
| SI: | Sustainability Institute |
| Td: | Transdisciplinary |
| TSAMAHub: | Transdisciplinary, Sustainability, Analysis, Modelling and Assessment Hub. |
| US$: | United States dollars |
| v.r: | variance ratio |
| WAT: | weeks after transplanting |
| WHO: | World Health Organisation |
| WV: | wild vegetables |
| Zn: | zinc |
| %: | percent |

# CHAPTER 1

# GENERAL INTRODUCTION AND THESIS STRUCTURE

## 1.1 Background and rationale

Hunger, malnutrition, diseases and rural poverty are some the current challenges facing South Africa (Pauw, 2005). Numerous studies have reported that a considerable proportion of the population in both urban and rural areas in South Africa is food insecure[1] (e.g. Altman *et al*., 2009) and suffer from malnutrition especially vitamin and micronutrient deficiencies (Faber and Wenhold, 2007; Faber *et al*., 2007) a phenomenon described as hidden hunger (Harvestplus, 2011; Tisdale *et al*., 1990). The estimates of the affected people seem to vary between different studies, and this has been attributed to the absence of a widely agreed standard of what constitutes food (in)security (Altman *et al*., 2009). As a result the statistics are highly variable.

Micronutrient malnutrition affects more than half of the world population, particularly in developing countries (WHO, 2000). In 2000, the World Health Report identified iron, vitamin A, zinc and iodine deficiencies as the most serious health constraints worldwide (WHO, 2000; see also Faber and Wenhold, 2007). Elsewhere, estimates indicate that about 265 million people in sub-Saharan Africa are undernourished (FAO, 2009). The same report also notes that the number of undernourished people has been increasing from the 1990s. Among others, one of the major reasons for poor nutrition is reduced agricultural production due to low and erratic rainfall and poor soil fertility. Southern Africa, especially South Africa is a region noted for rainfall variability and weather related risks. Most areas in South Africa are prone to drought, which may take the form of erratic onset of rains, early end of rains, dry spells during the rainy season, and reduced average seasonal rainfall. A recent study of South Africa's climate trends by Blignaut *et al*. (2009) reveals that all provinces except the Western Cape received progressively less rainfall since 1970. The country as a whole received on average 40 mm less annual rainfall in the last 10 years. In the

[1] What food insecurity really is and what causes it are subject to debate and varied interpretations (Altman *et al*, 2009) but in this study we can certainly say that poor soils and recurrent droughts do contribute as they invariably lead to low or no food yield.

same period the country has been 2% hotter (Blignaut *et al*., 2009). Inadequate and unpredictable rainfall invariably causes reduced yields, especially in the smallholder farming sector where farmers cannot afford irrigation infrastructure. Recent recurrent droughts in Southern Africa which have been attributed to climate change, namely the *El nino* weather phenomenon (see for example Mason, 2001; FEWSNET, 2009), have contributed to food insecurity in vulnerable rural and urban communities.

Most communities affected by poverty and under nutrition live in areas rich in biodiversity including wild vegetables (Reinten and Coetzee, 2002; van den Heever, 1995). In sub Saharan Africa, wild vegetables are important dietary components which are used to prepare sauces and relish that accompany carbohydrate staples like *pap* in South Africa, *sadza* in Zimbabwe, *fufu* in West Africa and *ugali* in east African countries. The main role of vegetables is as relish, that is, they are used as an accompaniment for staple maize meal known as phutu, pap or sadza, made mainly from maize meal. This staple maize meal which is a form of stiff porridge is eaten across Africa from west to east Africa and southern Africa. Relish is an indispensable part of the African diet since the staple maize meal is not normally eaten without relish (Oniango, 2003; Mavengahama, *et al*., 2013). Thus relish directly affects the consumption of the bulk of the main staple even though it (relish) may be consumed in smaller quantities. Indigenous vegetables are cooked by boiling and made into relish by adding various additives and seasoning. Although one type of vegetable can be cooked, usually two or more types of these vegetables are mixed and cooked together.

Several studies conducted on indigenous vegetables have implied that they generally have higher levels of various micronutrients than the conventionally cultivated[2] species (Dlamini et al., 2010; Flyman and Afolayan, 2006; Ndlovu and Afolayan, 2008; Ohdav *et al.*, 2007; Steyn *et al*., 2001; Nesamvuni *et al*., 2001). Wild vegetables are locally available and therefore inexpensive for low income sectors of the economy (Odhav *et al*., 2007; Steyn *et al*., 2001). Studies indicate that these vegetables still play significant roles in nutrition, food security and medicine (Jansen van Rensburg *et al*., 2007; Steyn *et al*., 2001; van Wyk and Gericke, 2000).

[2] Elsewhere in this study they are also referred to as exotic vegetables.

Recently, their medicinal properties have started being scientifically verified (Mackraj, 2007).

Although edible indigenous plant species have been utilised as food for centuries (Vorster *et al*., 2008; Adebooye and Opabode, 2004) and in spite of their noted good nutritional value, indigenous vegetables have not been widely domesticated and are not cultivated on a wide scale, especially in South Africa. Their utilisation is highly variable (Jansen van Rensburg *et al*., 2007) and they are mostly gathered from cultivated fields, fallowed land and the veldt (Venter *et al*, 2007). A National Food Consumption Survey (NFCS) study of food consumption patterns of one to nine year old children revealed that in KwaZulu-Natal, green leafy vegetables ranked a distant 20$^{th}$ among the most frequently consumed food behind other staple foods (Labadarios, 2000 cited in Faber *et al*., 2007). Even when exotic species are taken into account, the amounts of vegetables consumed in South Africa have been reported to be far below the recommended intakes (Maunder and Meaker, 2007). Wild vegetables have received little research attention (Modi *et al*., 2006; Mauyo *et al.*, 2008). There is a noted general decline in the use of wild vegetables by many rural communities in South Africa and this has contributed to poor diets and increased incidences of nutritional deficiencies (Jansen van Rensburg *et al*., 2007; Modi *et al*., 2006; Medisa and Tshamekang, 1995; Shackleton 2003 Steyn *et al*., 2001; Department of Agriculture, Forestry and Fisheries (DAFF), 2013)

The current manner of utilisation of indigenous vegetables relies on harvesting without cultivation. This may be regarded as exploitative[3] and therefore unsustainable in view of increasing population and could lead to genetic erosion (see Flyman and Afolayan, 2009a) and possible loss of biodiversity as noted by Shackleton (2003). Uprooting of whole tender plants is one of the observed methods of harvesting (Masarirambi *et al*., 2010; Agricultural Research Council – Vegetable and Ornamental Plant Institute (ARC – VOPI), 2012) and is a method that ensures that there is no seed production. Kwapata and Maliro (1995) have suggested that in some cases this decline is due to chemical elimination. This is especially true in

[3] Exploitative here refers to the current utilisation practice of harvesting without cultivation. This may pose problems when more people begin to consume as this would exert pressure on the naturally occurring populations even though the practice may not have posed problems hitherto.

Southern Africa where agricultural education in both commercial and communal areas was aimed at cash crop production. This type of farming promoted monoculture and emphasized the eradication of any other plant species from the field.[4] This same attitude towards indigenous vegetables still prevails among researchers and extension workers who still advise farmers to remove them from their fields (Vorster *et al*., 2007; Shackleton, 2003). The utilisation is also unsustainable in that the benefiting people have no control over availability as they do not cultivate these vegetables, thus, availability is unpredictable and variable. Flyman and Afolayan (2006) have suggested that reliance on exotic[5] vegetables is the primary reason for the decline in Southern Africa. Lack of knowledge about nutritional composition, cooking methods as well as ways of preservation have also been suggested as reasons for low use of indigenous vegetables (Flyman and Afolayan, 2006b). Mnzava (1997) referred to `strongly localized importance' as also reducing utilisation. This localized importance has also been alluded to by Jansen van Rensburg *et al*. (2007) who reported that although *Corchorus* spp. (Jews mallow or wild okra) occurs in Limpopo, KwaZulu-Natal and Eastern Cape, it is only consumed in Limpopo because people in the other provinces do not like its sliminess. Vorster *et al*. (2008) have suggested that the indigenous knowledge base of these vegetables has been eroded due to socio-cultural and environmental changes brought about by urbanisation, labour migration, and the emphasis on cash crop production instead of subsistence farming.

Besides nutritional benefits, it has been suggested that the utilisation of these vegetables represents significant savings of cash in the household (Shackleton, 2003). An alternative to this approach is the integration of indigenous vegetables in the cropping systems. The domestication of wild vegetables may contribute in solving the problem of nutritional deficiencies in the rural communities of South Africa and other developing countries (Mhlonto *et al*., 2007) as they provide a source of livelihood in difficult times (Dovie *et al*., 2007). This domestication can also result

[4] Indigenous vegetables can be regarded as weeds in the smallholder sector depending on where they occur in the farm. Those that occur in the field where crops are grown are usually removed as weeds but can be left untouched during weeding if the farmer wants to eat them. Usually those that grow at the edge of the field are harvested as vegetables.

[5] In this study exotic vegetables are those leafy vegetables that were introduced from other continents recently and mostly include varieties of the *Brassica* family such as cabbages, rape, spinach, covo, chomoullier.

in increased agro-biodiversity which has been shown to support food security as well as buffering against unfavourable environmental conditions, pests and diseases (Venter *et al*., 2007).

## 1.2 Justification

In spite of several studies having been conducted in various parts of South Africa with respect to indigenous vegetables, there are still many gaps in knowledge that remain. These gaps include, among others, the following:

- The willingness of people to formally adopt these vegetables as cultivated crops may be influenced by perceptions, cultural beliefs, values and social stigmas attached to these vegetables. The question may be asked: Do people view these plant species as important staple vegetables? or, as according to Shackelton *et al.* (2006), just as `safety nets' to be used when there is not enough food during droughts, famine or lack of money to purchase exotic vegetables.
- The nutritional composition of indigenous vegetables is not fully understood. The amounts of nutrients reported for the same species from different studies vary widely (also alluded to by Uusiku *et al*., 2010). The question then is what factors affect the nutritional composition of these vegetables? More controlled experiments on aspects such as effect of soil type, effect of fertiliser amount and type, and age of harvesting need to be conducted. The bioavailability of micronutrients also needs to be determined for cooked vegetables as most of the available data are on raw samples (Uusiku *et al*., 2010).
- The abundance and diversity of these vegetables have not been adequately determined. Diversity studies are especially important as a preliminary step in breeding of these species for desirable traits like low anti-nutrients and low astringency, high micronutrient content as well as high yield of the edible parts.
- The possibility of increasing the quantities as well as enhancing nutritional composition of these indigenous vegetables through domestication and improved agronomic practices such as fertiliser application.

There is need for continuous in-depth participatory studies on the indigenous knowledge systems about these species as well as on the current importance of these vegetables in the household economy. The potential of these vegetables to contribute to agro-biodiversity at farm (household) level through intercropping them with other crops needs to be explored. Studying how indigenous vegetables can be integrated into farming systems requires a holistic or transdisciplinary approach. This is because the utilisation of these vegetables is affected by many factors, among them, the availability of money to purchase alternative foods, the quantities needed by households, cultural and traditional beliefs, ascribed social status emanating from their utilisation, and the policies and teachings of the local agriculture department (e.g. how agricultural extension officers view these species) (Shackleton, 2003). The locus of decision making in the home is also likely to determine which crops are grown and which are not. In a household or a community where decision making is vested in males, indigenous vegetables are likely to be given last preference because they have been reported to be mostly the woman's domain (Vorster *et al.*, 2007; 2008).

In the literature, and in various discussion forums, there are widely varying opinions as to the importance, abundance, and ease of cultivation of these vegetables and even on the need to domesticate and cultivate them, yet not much empirical evidence is available to support or rebut these observations. Some researchers have suggested that indigenous vegetables are widely and freely available and abundant and therefore there is no need to cultivate them since these vegetables are only needed in smaller quantities and the naturally occurring amounts should be adequate. Yet others have indicated that very large quantities of raw vegetables are required to make just a small portion/serving of relish (Oelofse, 2010) Other researchers have reported that rural people perceive the populations of indigenous vegetables to be in decline (Shackleton, 2003; Vorster *et al*., 2008). In this study we argue that for seemingly abundant vegetables such as *Amaranthus* spp. (pigweed) and *Bidens pilosa* (black jack), people do not indiscriminately consume all available plants but select depending on certain (un) desirable characteristics like leaf hairiness, astringency (bitterness) and leaf size (which influences ease and speed of gathering/harvesting). As a result, not all that is available is consumed. There is still need for researchers to closely interact with people so as to clearly understand the peoples' perceptions and utilisation patterns at household level with respect to these vegetables. We also argue that if these vegetables are mostly used in times of food shortage in the home, then there is also likely to be a shortage of other necessary ingredients and other seasoning additives that make any relish tasty. As a result both adults and children would associate these vegetables with poor taste, which might not be a feature of the vegetables but a result of inadequate ingredients.

During our periodic transdisciplinary (Td) group meetings questions were raised as to the feasibility of cultivating these plant species and whether these vegetables are able to contribute to food security in terms of food bulk[6]. These emerging questions gave impetus to this present study, as we sought to gain a better understanding of people's perceptions of these vegetable species by conducting a survey and characterising the chemical composition through empirical studies.

There is a growing recognition that the present problems with food insecurity and poor nutrition need an integrated approach that takes cognisance of the complex nature of integrated rural poverty so as to achieve synergies through the integration of various disciplines to find a solution to the problem (see McLachlan and Garrett, 2008). Maunder and Meaker (2007) have also concluded that the combined effort of nutritionists and agriculturalists is needed to promote and enhance the utilisation of indigenous vegetables as part of the crops at household level. Similarly, in a study on the utilisation of these vegetables among the VhaVhenda people, Nesamvuni *et al*. (2001) encouraged health educators to promote the nutritional advantages of indigenous vegetables.

The present study sought to contribute to the knowledge on household food insecurity through researching the role of underutilised species in food security in subsistence households with particular reference to indigenous leafy vegetable species[7]. The study also aimed at researching the place of these vegetables in the

[6] This question led to a discussion on the real meaning of food security. Does it refer to availability of staple food in bulk or can we say a population is food secure if they have enough of their staple even though nutrients may not be balanced and may need to be supplemented. See FAO, (2009);Jacobs (2009); Altman et al, (2009) and Hart, (2009) for a detailed discussion of food security

[7] In this dissertation these types of vegetables are referred to as indigenous vegetables or wild vegetables and the terms are used interchangeably throughout the thesis.

subsistence cropping systems and to evaluate how these vegetables are accommodated in the spatial and temporal arrangement of plants at the farm level. It has been argued that indigenous vegetables have a weedy habit and therefore are likely to out-compete traditional conventional crops. There is likely to be a conflict between these new crops and the traditional crops and it might take a long time before farmers can change their attitudes towards these vegetables, which although used as food, have been largely viewed as weeds.

### 1.3 Description of the Problem

The issues of food shortages and poor nutrition affect many households in both urban and rural areas in South Africa. A combination of erratic and insufficient rainfall and poor soils contribute to food insecurity among households involved in primary production. This food insecurity is compounded by reliance on introduced and un-adapted crops that require high water and fertility levels, which are almost always limited in the smallholder farming sector. However, the affected people usually live among a wide range of adapted indigenous vegetables which they are not utilising on as a large a scale as exotic vegetables. The reasons for the low consumption are not yet well understood. The availability of these vegetables is also seasonal and they are available mostly in summer. This means vulnerable families who rely on gathering them during summer are left without a part of their diet for the greater part of the year from autumn, through winter to spring.

### 1.4 Study goal

The goal of this study was to contribute to knowledge on local people's perceptions of indigenous vegetables. They have traditionally been gathered and utilised as relish during hard times but their food security potential and their reported good nutritional status have not been fully realised to date. The study also sought to determine their nutritional composition and their response to selected improved agronomic practises so as ensure a sustainable and reliable supply.

### 1.5 Research Questions

The research questions were:

1) What knowledge and perceptions do indigenous people have concerning indigenous vegetables and how do this knowledge and perceptions influence

the utilisation of these vegetables? How is knowledge about these vegetables passed on from generation to generation? Are there differences in these perceptions between gender groups or between age groups?

2) What is the nutritional composition of indigenous vegetables occurring in various parts of the country? Are there significant differences in the micronutrient content of different indigenous vegetables? Do indigenous vegetables have superior micronutrient composition when compared with the more commonly utilised exotic vegetables such as B*rassicas* and other green leafy vegetables?
3) Do indigenous vegetable have the ability to accumulate more micronutrients in their tissues than the currently grown exotic vegetables?
4) How do soil amendments (mineral fertilisers and organic manures) affect the yield and nutritional composition of selected indigenous vegetables?
5) Besides soil fertility what other agronomic issues have the potential to hamper the growing of indigenous vegetables?
6) Are indigenous vegetables important in the farming systems in South Africa and is there potential for their increased utilisation in the subsistence farming sector?

### 1.6 Objectives

The broad objective was to document information on local people's knowledge and perceptions on the utilisation of indigenous vegetables characterize the nutritional composition, investigate the responses of these vegetables to agronomic and cultural practices and document the spatial and temporal occurrence and distribution of these vegetables and consumption levels and patterns.

The specific objectives were:

1) To gain an understanding of the perceptions and indigenous knowledge possessed by the local people with respect to indigenous vegetables and to investigate the extent of integration of indigenous vegetables as formal crops in both rural and urban farming systems.
2) To conduct a literature review on previous studies comparing the chemical composition of indigenous vegetables occurring in various parts of South Africa with exotic vegetables.

3) To comparatively investigate the effect of soil applied micronutrient and macronutrient fertilisers on nutritional composition of selected indigenous vegetables and exotic vegetable species.

4) To evaluate the yield performance of selected indigenous vegetables in response to soil applied inorganic and organic fertilisers.

5) To investigate how crop plant biology phenomena such as seed dormancy and flowering habit affect the propagation and cultivation of selected indigenous vegetable species.

6) To identify the present and potential roles of indigenous vegetables in the subsistence farming sector.

### 1.7 Outline of the thesis

The thesis is written in publication format with each chapter having its own separate introduction, materials and methods, results, discussion and reference sections. However, this being a transdisciplinary study there is a general introduction, a general literature review and general discussion and recommendation sections. These general sections are intended to illustrate the conceptual relationships between the various studies and show that although the chapters have been written separately, there are intricately linked. The structure of the thesis also necessitates that some themes and sections be repeated in the different sections since each all of the research chapters share the same introduction and literature review.

Chapter 2 presents the conceptual and theoretical frameworks of the study. In this chapter concepts are interrogated and placed in the context of the study.

Chapter 3 reviews literature that is common to all the sub-studies of this broad research. General research methods are presented in Chapter 4. These are methods that cut across all the studies undertaken. A justification for a Td approach for this study is given in this chapter. Chapter 5 reports the results of a survey that was undertaken in KZN. It mainly reports on the perceptions and knowledge of wild vegetables of the Zulu people. Chapter 6 presents the results of an experiment in which the response of two wild vegetable species to micronutrients added to the soil was evaluated. In chapter 7 the results on the yield response of the wild vegetable *Corchorus olitorius* to basal and top dressing soil amendments are reported. Chapter 8 reports on the results of a germination experiment on some morphologically different accessions of one of the wild vegetables occurring in KZN, *Corchorus olitorius*. The problem of premature flowering, encountered in growing *Cleome gynandra* is reported in chapter 9. Chapter 10 is an analysis of the challenges that are encountered in our quest to understand the nutritional value of wild vegetables. Chapter 11 is a critical review of the role of wild vegetables in the subsistence farming sector in South Africa and Chapter 12 presents the general conclusions and recommendations.

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# CHAPTER 2

# CONCEPTUAL AND THEORETICAL FRAMEWORK

## 2.1 Conceptual Framework

In this chapter main concepts are defined and analysed so as to set the context of the study. These main concepts are: transdisciplinarity, indigenous vegetable also referred to as wild vegetables, African leafy vegetables, and weeds and also known by various other vernacular names. The other concepts that permeate the study are those of food security, subsistence agriculture, agro-biodiversity and the household. The theoretical setting of the study is also illustrated diagrammatically.

### *2.1.1 Transdisciplinarity*

This research was conducted under the aegis of the TsamaHub (Transdisciplinary, Sustainability, Analysis, Modelling and Assessment Hub) through its Transdisciplinary (Td) PhD Programme in Sustainability. TsamaHub is an academic and research centre of Stellenbosch University (SU). Two departments from SU (Soil Science and Human Nutrition) then agreed to accommodate and supervise the research project on a 50:50 basis, with Soil Science as the host department. As such, the research was not grounded in a single discipline but rather attempts to highlight the existing but often overlooked connections between agriculture, human nutrition and other disciplines (more information on this study model can be found at www.tsama.org.za).

Transdisciplinarity is defined differently in different institutions. For example, this present study, which researches socially relevant problems, becomes a transdisciplinary study. Other requirements for a study to be transdisciplinary are that those involved have a major stake in the issue, there is societal interest in improving the situation, and sometimes the issue is under dispute (Pohl and Hirsch Haddon, (2007) cited in Stauffacher and Mollinger[8]). In this research, indigenous vegetables are being studied from a broad viewpoint – their contribution to food bulk as well as

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[8] Presentations to the Transdisciplinary research group at Stellenbosch University via satellite in January 2010 and also during the Transdisciplinary and Sustainability Summer School at Stellenbosch in January 2011.

to mineral nutrition, thus, bringing together the disciplines of agriculture and human nutrition, which is a branch of the health sciences.

The complex[9] nature of society necessitates the recognition of perceptions and actions, and demands the use of soft system methodologies commonly referred to as participatory methodologies (Schierre, 2005) when dealing with societal problems. Transdisciplinarity can also be viewed in terms of going beyond disciplinary boundaries in attempting to solve a social problem which is not clearly defined. In this current study the disciplines of human nutrition, sustainable agriculture (which itself can be regarded as already transdisciplinary), social sciences and ethno-botany are being transcended.

### *2.1.2 Indigenous vegetables, wild vegetables or weeds?*

The vegetables that are the subject of this research have been known by different names (see Section 3.1). In exploring the concept of indigenous vegetables, their etymology would inevitably have to be tackled. The origins of some of these plants and their names are obscure. Although they are referred to as indigenous vegetables, some of them were introduced to Africa many centuries ago such that they have become more of ‘indigenised’ and are not indigenous in the strict sense of the word. Thus, some scholars have referred to them as indigenised and endemic (Mark Swilling, 2010).

The dual agriculture structures (subsistence and commercial) especially in southern Africa has resulted in conflict as to the identity of plant species that occur in cultivated lands and compete with crops for nutrients and yet these same plants can be harvested and eaten as relish. These plants are referred to as weeds in commercial and even communal (subsistence) agriculture[10]. However, in the subsistence agriculture sector these plants are consumed as food (vegetables) but when they occur in cultivated fields they are removed as weeds although in some cases selective weeding is done so as to leave them in the field. They are generally tolerated weeds because of their food value.  In commercial agriculture these plant

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[9] See Cilliers, P, 1998, 2000, 2005; Allen, P. 2000, 2001 and Chu, *et al*. 2003 for a detailed discussion of complexity theory.

[10] Personal experience of the author. I grew up eating these plants but we still called them weeds

species have been invariably treated as weeds and have to be removed from the field. The farming in the commercial sector is a business and therefore geared towards profits. Mono-cropping is mainly practised with very effective weeding methods (herbicides and mechanical weeders) used to eliminate any other plant species from the fields. There is therefore, a conflict as to how these species should be regarded. The same people who provide weeding labour on the commercial farms refer to these same plants as weeds when they are at work yet when they get back to their rural homes they utilise them as vegetables. However, it would appear that the name weed lingers and has also come to be used in the subsistence sector, partly because after independence, the governments in southern Africa extrapolated the production practices in the commercial sector and introduced them in the subsistence sector, with the result that the same vegetables have to be removed from fields. That not much cultivation and research has been done about these vegetables points to the uncertainty as to how to regard them.

Several wild plant species are utilised as vegetables in Kwazulu-Natal, especially among the rural population *Amaranthus dubius, Amaranthus hybridus, Amaranthus spinosus, Asystasia gangetica, Cucumis metuliferus, Cleome gynandra and monophyla, Ceratotheca triloba, Galinsoga parviflora, Justicia flava, Mormodica balsamina, Physalis viscosa* and *Wahlenbergia undulate.* Some of these species are illustrated in Figures 2.1 and 2.2.


a


b


c


d


e


f

**Figure 2.1** Some of the wild/indigenous vegetables in northern KwaZulu-Natal; (a) Cat's whiskers (*Cleome gynandra*), (b) Black jack (*Bidens pilosa*), (c) black nightshade (*Solanum nigrum*), (d) Galant soldier (*Galinsoga parviflora*), (e) *Mormodica balsamina* and (f) *Commelina africana*.

**Figure 2.2** Five different biotypes of *Amaranthus* in northen KwaZulu-Natal. Note the differences in growth habit, leaf size and leaf colour.

*2.1.3 Subsistence cropping systems.*

Most rural households practise subsistence agriculture, which is mostly characterised by mixed crop farming with a mixture of small and large livestock. Productivity is usually low due to various constraints, among them lack of inputs, poor soils and erratic rainfall. The growing season is limited to a few months of the year when rains are available (summer). It is within this setting that indigenous vegetables can a play significant role in alleviating the shortage of relish and providing micronutrients which are in short supply. Their near ubiquitous occurrence ensures that most households have access to them when they are available during the summer season. They are also hardy and tolerant of adverse climatic conditions so as to be available during either droughts or flood periods. However, their availability follows the rainfall season. There is, therefore, a shortage during the autumn, winter and spring seasons. This means that production of these vegetables would have to take place in the home gardens if they are to be available all year round. If they are to be grown off-season there will be need to select and breed for tolerance to low winter temperatures and the removal of seed dormancy to promote germination.

Subsistence farmers generally produce their vegetables on small plots either in home or community gardens. Yet indigenous vegetables grow in the fields or on the roadsides and the veldt. The spatial arrangement of plants at the farm would influence the cultivation of these vegetables since they would have to fit into an existing cropping programme at the farm. The following questions could be asked: Will farmers be willing to grow them as mono-crops as they do cabbage and spinach? Since they are not yet domesticated and have a weedy habit will they not out-compete crops when intercropped? Negative perceptions about these vegetables also lead to people not eating them even though they may want them. Indigenous vegetables are also regarded as food for the poor and some needy people who may derive utility from them may still go hungry because they do not want to be ridiculed and labelled as poor, even though that may be the case. It is also possible that their cultivation will also lead to their conservation and contribute to agro-biodiversity especially at the farm level.

### *2.1.4 Household*

The household exists within the greater socio-political hierarchy of the village, ward, district and existing communities. It is made up of the animate (humans, livestock, crops and other organisms) and the inanimate (weather elements, rocks and the mineral fraction of the soil, water bodies) and is thus part of both the ecosystem and society. The term household could be applied to humans only, or could refer to humans and their dwellings and belongings (Mtshali, 2002). Other concepts that could be used interchangeably with household are family or homestead, the later especially applying to rural settings. The concept of the household itself can be quite complicated in the African setting, with another concept, that of the homestead, which can be a household at times or be a collection of households of the extended family (Mtshali, 2002)

### *2.1.5 Food security*

In this study we posit that food security can be at macro (national or regional) level or micro (household) level and that it can be in terms of food bulk and also be looked at in terms of the nutrients in the diet. A question could be asked thus, if a household has enough maize to provide adequate phutu throughout the year but always struggles to get relish, can this family be regarded as food secure? In this study we argue that such a household may not be food secure.

In Africa food security tends to focus at the bulk of the staple crop rather than at whether the diet is balanced – that is, whether all the essential nutrients available in their correct proportions. This was also reported by Mapanda (2011) who stated that maize is generally used as the food security indicator in Zimbabwe in particular and in Africa in general. There are thus disparities in how food security is measured at national and at household level. Generally looking at food security from a wider scale has the effect of concealing the shortages or deprivation at household level. This is because commercial agriculture can lead to very high yields and contribute to national food sufficiency yet at household level in the smallholder (communal) sector) there is no food – generally commercial agriculture utilises irrigation infrastructure, inputs such as fertilisers, chemicals, labour and appropriate farming knowledge.

With respect to indigenous vegetables, their potential to contribute to household food security is contested - some have indicated that since these vegetables are needed only in small quantities as relish, as such they cannot play a significant role in food security. Yet in the household without relish these vegetables influence the consumption patterns and levels of staples like maize, sorghum, millets – whose consumption relies on the availability of relish. There are some foods that contribute significantly to rural household food basket; such as foods from the wild – indigenous vegetables, fruits, mushrooms, bush meat which are usually not included in national foods baskets

## 2.2 The theoretical framework

The theoretical framework presents the major relationships and interests in this study by showing the interactions between nutrition (represented by indigenous vegetables) and the stakeholder groups, the identified causes and the possible outcomes. The theoretical setting of the study is illustrated in the Figure 2.3.

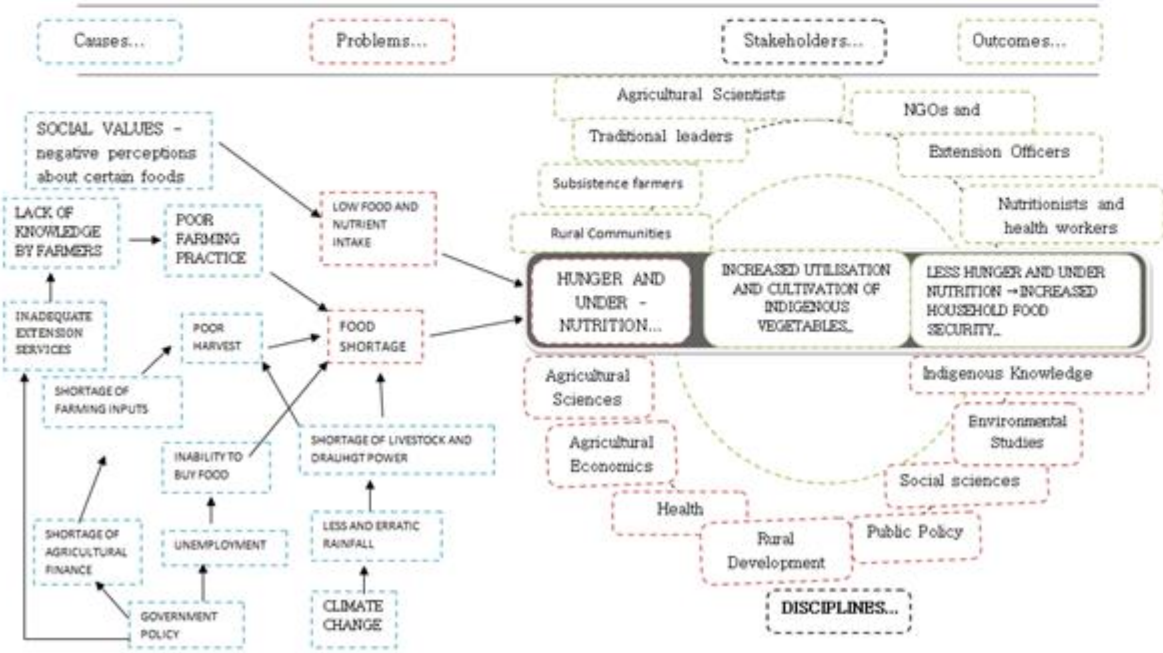


**Figure 2.3** Conceptual framework showing some causes of food insecurity and how indigenous vegetables can be integrated to alleviate household food insecurity

## 2.3 References

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# CHAPTER 3

# A review on wild vegetables in South Africa[11]

## 3.1 Occurrence, distribution and etymology of indigenous vegetables

Studies on indigenous vegetables have been conducted in different regions of South Africa namely in Limpopo Province (e.g. Steyn *et al.*, 2001; Nesamvuni *et al*., 2001; Vorster *et al*., 2007), KwaZulu-Natal (e.g. Modi *et al*., 2006; Odhav *et al*., 2007; Vorster *et al*., 2007) and in Eastern Cape province by Vorster *et al*. (2007). The studies concur that some species of uncultivated indigenous vegetables (e.g. *Bidens pilosa* (black jack), A*maranthus* (pigweed) and *Cleome* spp (spider flower/cat's whiskers) commonly occur across provinces. According to van den Heever (1995) "the most popular species in South Africa are": *Taraxacum officinale* (dandelion), *Bidens pilosa* (black jack), *Chenopodium album* (common lambsquarter), *Cleome gynandra* (bastard mustard), *Portulaca oleracea* (common purslane) and *Amaranthus* (pigweed). Jansen van Rensburg *et al*. (2007) listed the following as "important leafy vegetable species in South Africa": *Amaranthus* spp. (amaranth), *Cleome gynandra* (spider flower), *Brassica rapa* L. subsp *Chinensis* (Chinese cabbage), *Solanum nigrum* (nightshade), *Corchorus olitorius; Corchorus tridens* (Jews mallow). Cultivated pumpkins and melons (*Cucurbita* spp.) and cowpeas (*Vigna* unguiculata) are often also recorded as indigenous vegetables. The following habitats were listed by Odhav *et al*. (2007) as places where indigenous vegetables were found: cultivated land, disturbed land, roadside, sandy shade and grassland.

From the literature, two broad groups of indigenous vegetables emerge, the cultivated leafy vegetables like pumpkins (*Cucurbita* spp.) and cowpeas (*Vigna unguiculata*)[12] and the uncultivated ones which mainly grow as volunteers in cultivated fields. The latter are invariably regarded as weeds in commercial agriculture but can selectively be regarded as either weeds or vegetables in

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[11] Sections of this chapter were published in Scientific Research and Essays as Lewu, F.B and Mavengahama, S. 2010. Wild vegetables in northern KwaZulu Natal, South Africa: Current status of production and research needs. Scientific Research and Essays 5 (20): 3044 - 3048

[12] In this study the name `indigenous vegetables' is used to identify non-cultivated plant species that occur naturally in various places and are gathered and utilised as vegetables. It does not include cowpeas (*Vigna unguiculata*) and pumpkins (*Cucurbita* spp) as these two are cultivated species even though they are also known as *imfino* or *morogo*

subsistence farming systems depending on whether the particular species is utilised as a vegetable or not in an area or in a specific cropping enterprise. There are many names by which indigenous vegetables are known by different authors including African leafy vegetables (Jansen van Rensburg *et al*., 2007), traditional leafy vegetables (Vorster *et al*., 2008; Odhav *et al*., 2007), wild vegetables (Nesamvuni *et al*. (2001). Ethnic groups in South Africa have their own names which vary from place to place. Collectively they are called *imfino* (isiZulu, isiXosa), *morogo* (Sesotho) or *miroho* (tshiVhenda) (Maunder and Meaker, 2007). According to Faber *et al.* (2002) *imfino* "is a collection of various dark-green leaves that is eaten as a vegetable; the leaves either grow wild or come from vegetables such as pumpkin and beetroot". The plant species that are referred to as *imfino* or *morogo* vary from place to place (Jansen van Rensburg *et al*., 2007) and the main method by which these vegetables are brought into homesteads is by gathering them from cultivated fields and from veldt areas in the communal areas.

### 3.2 Knowledge systems of indigenous vegetables

It has been reported that some indigenous knowledge about vegetables has been lost over time and this has been attributed to people's unwillingness to learn about them due to the low status ascribed to these vegetables as well as the reliance on exotic species (Vorster *et al*., 2008; Misra *et al*., 2008). This lost knowledge includes other less known edible species, preservation methods and indigenous seed systems. This decline in indigenous knowledge coupled with lack of knowledge about nutritional value has been cited as a reason for the decline in the consumption of indigenous vegetables (Mnzava, 1997). Findings by Modi *et al*. (2006) suggested that younger members of the community know less about indigenous vegetables than older members. The same study also found that middle aged participants' knowledge of indigenous vegetables increased with an increase in their education level. This may perhaps suggest that formal education systems like schools and colleges can be used to teach about indigenous knowledge systems. In spite of some research having been undertaken, more research is still needed to generate more information and knowledge on the role these vegetables could play in alleviating food shortages and malnutrition. Flyman and Afolayan (2006a) noted that current research efforts appear to be concentrated on only a few commonly utilised species which may have already been partially domesticated. This means there is an opportunity to generate knowledge on marginally utilised species which may have good potential to provide more nutrients in the diet. An understanding of the indigenous technical knowledge systems of these vegetables will enable researchers to come up with culturally appropriate cultivation and processing methods (Venter *et al*., 2007). Women have been identified as the major custodians of the knowledge on indigenous vegetables (Vorster *et al*., 2007; 2008), probably because they are mostly involved in the gathering, cooking and preservation of these vegetables.

Most studies on leafy vegetables have been conducted in universities and research institutes and have focused on routinely cultivated exotic crops (Keller *et al*., 2006). Although some studies have been conducted on some aspects of wild vegetables, our literature search has revealed that these studies have been done at academic institutions based on researcher interest rather than as a coordinated and sustained national or regional effort to domesticate and commercialise wild vegetables. Our informal communication with the Agricultural Research Council and National Department of Agriculture's gene banks has indicated that there are very limited collections of wild vegetable accessions (e.g. *Corchorus olitorius*) from the whole country. Very few, if any, of the wild vegetables in KwaZulu-Natal have had a complete and comprehensive study from the morpho-genetic characterisation, agronomic-chemical evaluation to the effects of cooking and processing on chemical and nutritional composition of these species. As a result there are many gaps in knowledge with respect to production requirements of wild vegetables. These gaps range from lack of germplasm from which genetic material for the development of new cultivars and improvement of current varieties can be obtained, to lack of information on germination requirements and agronomic practices. The worth of wild vegetables can be fully appreciated if they are comprehensively researched.

### 3.3 Studies on the nutritional composition of indigenous vegetables

Studies have been conducted on the nutritional composition of indigenous vegetables, generally indicating higher levels of vitamins and minerals compared with cultivated vegetables (Flyman and Afolayan, 2006b; Odhav *et al*., 2007; Faber *et al*., 2007; Uusiku *et al*., 2010)[13]. Some of these studies have mainly involved collecting from the wild and analysing for the various nutritional indicators like proximate analysis and mineral elements (Lewu and Mavengahama, 2010). An assessment of indigenous vegetables collected in KwaZulu-Natal by Odhav *et al.* (2007) revealed that twelve out of twenty vegetables provided mineral concentrations exceeding 1% of plant dry mass which is much higher than concentrations found in conventional exotic vegetables like cabbage and spinach. Fifty percent of the vegetables had significant energy values ranging from 50–70 kcal/100 g. For example, *Senna occidentalis* and *Wahlenbergia undulata* yielded the highest energy 84 kcal/100 g and 75 kcal/100 g respectively. Protein content ranged from 2 g /100 g in *Cerotheca triloba* to 7 g/100 g in *Senna occidentalis*. Three species were good sources of fat. The leaves of *Bidens pilosa* had very high fibre content (2.9 g/100 g). In a previous study on the leaves of wild okra (*Corchorus spp.*) conducted in the Eastern Cape, Ndlovu and Afolayan (2008) found that wild okra contains more crude protein than cabbage (*Brassica oleracea* L.) sold in the formal market. Chemical analysis of the same okra indicated that it contained more iron, calcium and magnesium than cabbage. In the study by Odhav *et al*. (2007), mineral levels were found to be high for all vegetables. Phosphorus content of the leaves varied and ranged from 38 g/100 g (*Galinsoga parviflora*) to 814 mg/100 g in *Asystasia gangetica*. These vegetables also had high copper and zinc concentrations. *Bidens pilosa* had the highest amount of copper (10 mg/100 g). *Chenopodium album* had a high zinc content of 109 mg/100 g dry mass. Vegetables may be rich in mineral nutrients but these nutrients may not be easily available (bio-availability) due to the anti-nutritional factors. Studies have shown that the mineral contribution of vegetables to human nutrition is limited due to the presence of anti-nutrients. The most common anti-nutritional factors in indigenous leafy vegetables are phytate, tannins, hydrocyanic acid and oxalic acid (Akwaowo *et al*., 2006). In plants, phosphorus is mainly stored in the form of phytate and is therefore abundant. Phytate has the ability to bind with polyvalent mineral ions like $Zn^{2+}$, $Fe^{2+}$ and $Ca^{2+}$ to form an insoluble precipitate. As a result of this precipitate these ions are not absorbed into the bloodstream (Lonnerdal, 2003; Gupta *et al*., 2006). This suggests

[13] Some research has already been done on what percentage of the Recommended Daily Intakes can be met by indigenous vegetables. Please refer to the various tables in Faber *et al*., (2007) and Uusiku *et al*., (2010). Due to space considerations the tables cannot be reproduced here.

that while laboratory results might indicate that vegetable leaves are rich in certain micronutrient elements, these elements will actually not be able to contribute to the nutrition of humans. These vegetables need to be characterized on the basis of anti-nutritional factors and where possible, molecular markers could be used to aid in the selection for low anti-nutritional levels and other undesirable characteristics.

### 3.4 Medicinal uses

It is estimated that 70% of the population in South Africa use wild vegetables as medicinal remedies (Venter *et al.*, 2007; van den Heever, 1995). Research at the University of KwaZulu-Natal has indicated that *Amaranthus hybridus, Amaranthus dubius, Asystasia gangetica. Galinsoga parviflora, Oxygonum sinuatum, Physalis viscosa* and *Tulbahgia violacea* may be of use in treating hypertension (Mackraj, 2007). In the same study, *Portulaca oleracea* and *Justicia flava* were found to have high levels of antioxidant activity; making them useful medicinally. Antioxidants are chemical compounds that can bind to free oxygen radicals preventing these radicals from damaging healthy cells (Subhasree *et al*., 2009). Free radicals are naturally produced in the body through the normal metabolism of amino acids and fats. These free radicals are unstable molecules that can freely react with and destroy healthy cells. They can bind to, and alter the structure of DNA thus leading to mutations and eventually to cancer (Mochiegani and Muzzioli, 2000). The reported high level of nutrients, especially zinc, has resulted in indigenous vegetables being recommended in the management of HIV and AIDS. Diets that are deficient in zinc have been linked to stunted growth and impaired immune systems (Lonnerdal, 2002). Zinc plays an important role in actively metabolising cells as well as in HIV positive people (Oyedele *et al.*, 2006) and has been previously reported as the most deficient nutrient in HIV infected patients (Mochegiani and Muzzioli, 2000; Baum *et al.*, 2003). In these studies low levels of zinc in blood plasma resulted in a threefold increase in deaths due to HIV whereas in individuals with optimal zinc levels there was a reduced disease progression and low incidences of opportunistic infections (Mochegiani and Muzzioli, 2000; Baum *et al.*, 2003).

### 3.5 Cultivation, preservation and off-season production of indigenous vegetables

The availability of uncultivated indigenous vegetables is dependent on the summer season when rainfall and other conditions are favourable for plant growth. This means that in areas with alternating wet and dry seasons these vegetables are not available for part of the year (see Modi *et al*., 2006; Faber *et al*., 2007) leaving vulnerable people without an important dietary component. There is need therefore to find ways of making these vegetables available during the off-season. A search in the literature indicates that there is a dearth of information on the practicability of cultivating indigenous vegetables off-season, possibly indicating that not much research has been undertaken.

The easy perishability of indigenous vegetables poses major challenges with their storage, distribution and marketing (Smith and Ezyaguirre, 2007; Medisa and Tshamekang, 1995). In Sub-Saharan Africa, drying is the major method of processing leafy vegetables to make them available during periods of scarcity. Whilst drying solves the problem of perishability, it does not satisfy the needs of a large population of consumers, particularly urban dwellers who prefer freshly harvested vegetables (Smith and Ezyaguirre, 2007). It is also not known how drying affects the vegetables in terms of nutritional value. In other vegetables species, especially the exotic species, it is documented that drying and storage for longer periods destroys vitamin C. Other constituents that are destroyed or altered during processing of wild vegetables need to be determined. If processing has the potential to impair the composition of these vegetables, there is need to explore ways of propagating these indigenous vegetables so that fresh indigenous vegetables are available all seasons. The use of home-gardens as a means of diversification of diets has been previously explored by some researchers (Maunder and Meaker, 2007; Faber and Benade, 2003; Faber *et al*., 2002). If it is feasible to grow indigenous vegetables off-season, home gardens would be the most appropriate as they have a water source and are protected. The integration of a home gardening programme with a primary health care activity was successfully used in addressing vitamin A deficiency in Ndunakazi, KwaZulu-Natal, South Africa (Faber *et al*., 2002).

### 3.6 Morphological characterisation and genetic Improvement of indigenous vegetables

Morphological characterisation provides the basis for identifying the variation on nutrients and health promoting traits among cultivars within a species (Smith and Ezyaguirre, 2007). Before the objective of plant breeding is pursued in any species, basic information on existing morphological variability in the cultivated species and their wild relatives is essential (Adebola and Morakinyo, 2006). In spite of the advantages of novel methods like molecular markers, morphological descriptor in genetic diversity is still important when exploring the possibility of choosing materials to be incorporated into breeding programmes (Sounigo *et al*, 1997). Morphological characterisation is a preliminary requirement for the exploitation of useful traits in plant breeding (Brandolini *et al*, 2000).

The conservation of genetic materials within indigenous or traditional vegetables and their wild relatives has received little attention in research and development programmes (Slikkerveer, 1995). This omission has contributed to genetic erosion of potentially important genetic materials (Schippers, 2002). Lack of prioritisation by African governments in terms of research is the major reason for genetic erosion (Adebooye and Opabode, 2004). Most studies on leafy vegetables and fruits in universities and research institutes have focused on routinely cultivated exotic crops (Keller *et al*., 2006). However, there is currently a realisation of the importance of indigenous vegetables and fruits to human nutrition, medicine and nature (Adebooye and Opabode, 2004). This realisation led to the establishment by the United Nations of the Institute for Natural Resources in Africa (INRA) during the year 1996 which is a unit of the United Nations University in Accra, Ghana. The mandate of this institute is research and training on conservation of African food plants diversity and soil conservation (Adebooye and Opabode, 2004). Plant genetic resources are the basic ingredients for biotechnology (Adebooye and Opabode, 2004) and conventional plant breeding. The collection of germplasms of indigenous leafy vegetables, fruits and spices and their wild relatives are essential to biotechnology and plant breeding research. Most African countries that are signatories to the Convention on Biological Diversity (CBD) of the United Nations Environment Programme and the Global Plan of Action on plant genetic resources of the Food and Agriculture Organisation (FAO) have identified a singular cause of genetic erosion in crops as the replacement of local varieties by exotic varieties and species (Adebooye and Opabode, 2004). The Agricultural Research Council (ARC) in South Africa established a Plant Genetic Resources Unit in 1995 (van den Heever, 1995) whose purpose is to make provision for coordination and liaison with international and regional plant genetic resources organisations. Specifically, the Vegetable and Ornamental Plant Institute initiated a project on indigenous leafy vegetables whose objectives are to start a selection and breeding programme to improve the yield and adaptability of promising species, to develop *in vitro* and other vegetative techniques to enable rapid multiplication of promising lines for use in the project and later to supply producers (van den Heever, 1995). One such study was carried out in Watershed, KwaZulu-Natal province. The study indicated there are limited efforts to conserve wild vegetables by the communities. It has been noted that some women occasionally collect seed of selected species such as *Momordica balsamina, Citrulus lanatus, Amaranthus spp*, *Cleome gynandra* and *Bidens pilosa* (Vorster *et al.*, 2007). As reported by Vorster *et al*. (2007), droughts and thunderstorms led to depletion of seedbanks. Drought led to over-harvesting of plants thereby reducing reproductive potential whilst the first thunderstorms (which are noted as the most common form of rainfall pattern in most areas) caused depletion of seed through washing away with top soil. The same researchers (Vorster *et al*., 2007) also found out that a non-governmental organisation had to re-introduce cowpeas in Watershed, KwaZulu-Natal, after farmers had lost both production information and seed over an extended period of time. In spite of this re-introduction, farmers still have high preferences for exotic species (Vorster *et al.*, 2007). As a result, only a few wild vegetables are being harvested causing many of the less utilised species to become scarce (Vorster *et al.*, 2007). Those who gather wild vegetables, mostly collect young and tender parts of the wild population thereby threatening sustainable utilization (Vorster *et al*., 2007).

### **3.6.1** *Constraints to propagation and conservation*

Several constraints to propagation and multiplication of indigenous vegetable species have been identified. Opabode and Adebooye (2005) have reported biological constraints which may hinder germplasm conservation efforts. These include numerous morphotypes for *Corchorus* spp. and *Celosia argentea*, seed dormancy for *Launea taraxicifolia,* low seed viability for *Solanecio biafrae* and recalcitrant seed for *Telfairia occidentalis. Telfairia* seed germination capacity declined when seed moisture was less than 40% and was completely lost when moisture content fell below 30%. Taxonomy is another production related constraint that has been encountered (Smith and Ezyaguirre, 2007). Indigenous vegetables are identified by their local names, but quite often the same local name is applied to two or more species. Non-availability of improved seed has been reported to be a major constraint to the few indigenous vegetables that are presently under cultivation (Adebooye *et al*., 2005)

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# CHAPTER 4

# GENERAL RESEARCH METHODS

## 4.1 Justification for a Transdisciplinary[14] approach

This research involved the integration of methods of both the social and natural sciences, such as ethnography and controlled experiments (Figure 4.3). From this perspective of integration, these qualitative and quantitative methods and controlled experiments were employed in a complementary way. Further, this research also integrated different knowledge systems and was driven by the three types of knowledge that underlie transdisciplinary studies *viz*. systems, target and transformation knowledge (see Hoffmann-Riem *et al*., 2008). The issues of poor and inadequate nutrition and food insecurity do not exist in isolation but are an integral part of the complex and dynamic social condition termed poverty. Poverty has been identified as a strong determinant of what Chambers (1990:112) referred to as `five clusters of disadvantage'[15] that affect the poor. These clusters of disadvantage are interconnected and related in such a way as to lead to what was termed the `deprivation trap', itself leading to `integrated rural poverty' (Chambers, 1990:112). The issues are not well defined, the relationship between cause and effect is not easy to attribute and is non-linear (Cilliers, 2000). As a result, in our attempts to deal with these issues we must take cognisance of the connections between them. These vegetables exist as part of complex biophysical-ecological and social system of the farm enterprise and their cultivation would affect other cropping activities at the farm. During the summer season these vegetables grow as volunteer plants when fields have been cultivated. In winter they are absent and if production is to be undertaken it would be in home gardens or other naturally moist areas like *vleis* so as to avoid costs associated with irrigation, which would render their cultivation unsustainable. The utilisation of these vegetables seems to be contextualized and may be influenced by differences in: cultural backgrounds which vary from one ethnic group to another, location *viz*. rural and urban dwellers, gender as well as differences in age. As a result, a study that may have been conducted in one part of the country

[14] See section 2.1.1

[15] For a detailed account of integrated rural poverty consult the book: Rural Development: Putting the last first by Robert Chambers, 1990.

will not necessarily be generalised to the rest of country or wide geographical regions. We are also faced with issues of attitudes, perceptions and priorities especially in terms of cultivating these species as they may be competing with cash crops that already have a market. Thus, for the challenge of poor nutrition to be properly understood, it must not be viewed in isolation just as a technical challenge but as a complex social issue (McLachlan and Garrett, 2008).

This study was collaboration between the University of Stellenbosch and the Sustainability Institute (SI) and smallholder sector farmers in selected parts of South Africa. Although the project was located in the Faculty of AgriSciences, the co-promoter was in the Division of Human Nutrition, Faculty of Health Sciences. The study was purposively located in districts where other food security studies were being conducted, for example, the project: `*Food Security Vulnerability and Climate Change in South Africa: A case study of KwaZulu-Natal*', which was a collaborative project between the government of Flanders and the KwaZulu-Natal Department of Agriculture and Environmental Affairs. The Centre for Agri-Leadership research at Stellenbosch University was also participating in this project. It was expected that the location of the study in a place where other projects were already running could lead to the creation of synergies as well as build on what others had done.

**4.2 Socio-economic background to northern KwaZulu-Natal, South Africa**

According to the National Census of 2001, KwaZulu Natal (KZN) Province has the highest population in the country, with 21.0% of the total population of South Africa. When the province's gross domestic product (GDP) was compared to its total share of the national population, it was revealed that the GDP is lower than the national average (Pauw, 2005; Mohamed, 2007). Agricultural households earn less than their non-agricultural counterparts, thus agricultural households are generally worse off. Poverty rates among agricultural households were found to be very high (81.2%) compared to non-agricultural households (49.5%). Poverty rates vary greatly between racial groups with the Africans (blacks) who constitute the bigger percentage of the population being the worst affected (poverty rate of 64.4%). Poverty is higher in rural areas (78.2%) than in urban areas (28.9%). The province is still challenged by high level of poverty especially among the African communities. (Pauw, 2005; van den Heever, 1995; Modi *et al.*, 2006)

## 4.3 Ethics, clearances and protocols

### *4.3.1 Stellenbosch University ethics committee*

The research proposal for the study was submitted to the Stellenbosch University's Ethics Committee and all requirements of this committee were complied with. It was thus approved.

### *4.3.2 Clearance for community entry and subsequent activities*

The researcher followed the protocol for community entry in the different areas. The researcher first made contact with local agricultural extension personnel who assisted in the community entry and subsequent activities. The agricultural extension personnel were the medium of communication between the researcher and community leaders (both traditional and political) and the communities.

### *4.3.3 Recruitment of personnel*

For all studies (survey and field experiments) suitable local people were employed. This was to facilitate the use of the local language (*isi*Zulu) in communicating with authorities and respondents. Also, local people knew the area very well, were acquainted with the local customs and taboos. The enumerators and facilitators were selected on the basis of their personality (open, polite and friendly) as well as fluency in both *isi*Zulu and English. This was because the questionnaire was in English but was translated to *isi*Zulu during the face to face interview. Training in this regard was provided. Other researchers (e.g. Mtshali, 2002) indicated that in KwaZulu-Natal there was some sensitivity to the gender of the enumerator or facilitator, with men preferring to be interviewed by other men and women preferring to be interviewed by other women. This required that the enumerators work in pairs since the gender of the household head respondent was not known beforehand.

## 4.4 Methods and research designs

This study was mainly exploratory and was conducted using mixed methods (Figure 4.3) under the umbrella of participatory methodologies. Participatory methodologies emerged out of the realisation of the need to involve communities in the research process, that is, in the framing, prioritisation and analysis of their problems and needs. (Anyaegbunam *et al*., 1998:20).Two major participatory processes can be recognised; Participatory Rural Appraisal and Participatory Learning and Action.

Participatory methodologies employ both qualitative and quantitative ways of creating knowledge and collecting data. The reasoning behind employing participatory methodologies was that this study sought to go beyond just analysing the problem but coming up with potential solutions, thus, with the researcher being a change agent. For this objective to be achieved, previous experience has shown that methodologies that involve the affected communities have to be employed. Participatory methodologies ensure that both the researcher and the intended beneficiaries frame the problem together, design the research together and find solutions together (see Anyaegbunam *et al*, 1998; Mefalopulos and Kamlongera, 2002). The study areas were selected purposively based on several criteria which included agro-ecological zones, history of previous research in the areas and others.

### *4.4.1 Survey study*

An ethno-botanical survey was conducted using a structured questionnaire to collect quantitative data on perceptions and attitudes to indigenous vegetables, and the diversity of the vegetables. The district municipalities were selected purposively. Households were then randomly selected for the face to face interviews. Determination of minimum sample size was done so as to achieve a maximum error of 5% at a 95% confidence level (Bartlett *et al*., 2001) One of the district councils (UThungulu) had a metropolitan area (UMhlatuze) and the other UMzinyathi, had a remote rural area (Figure 4.1). The household was the unit of analysis for the survey study. Quantitative data from the surveys were analysed using PASW 18 statistical package.

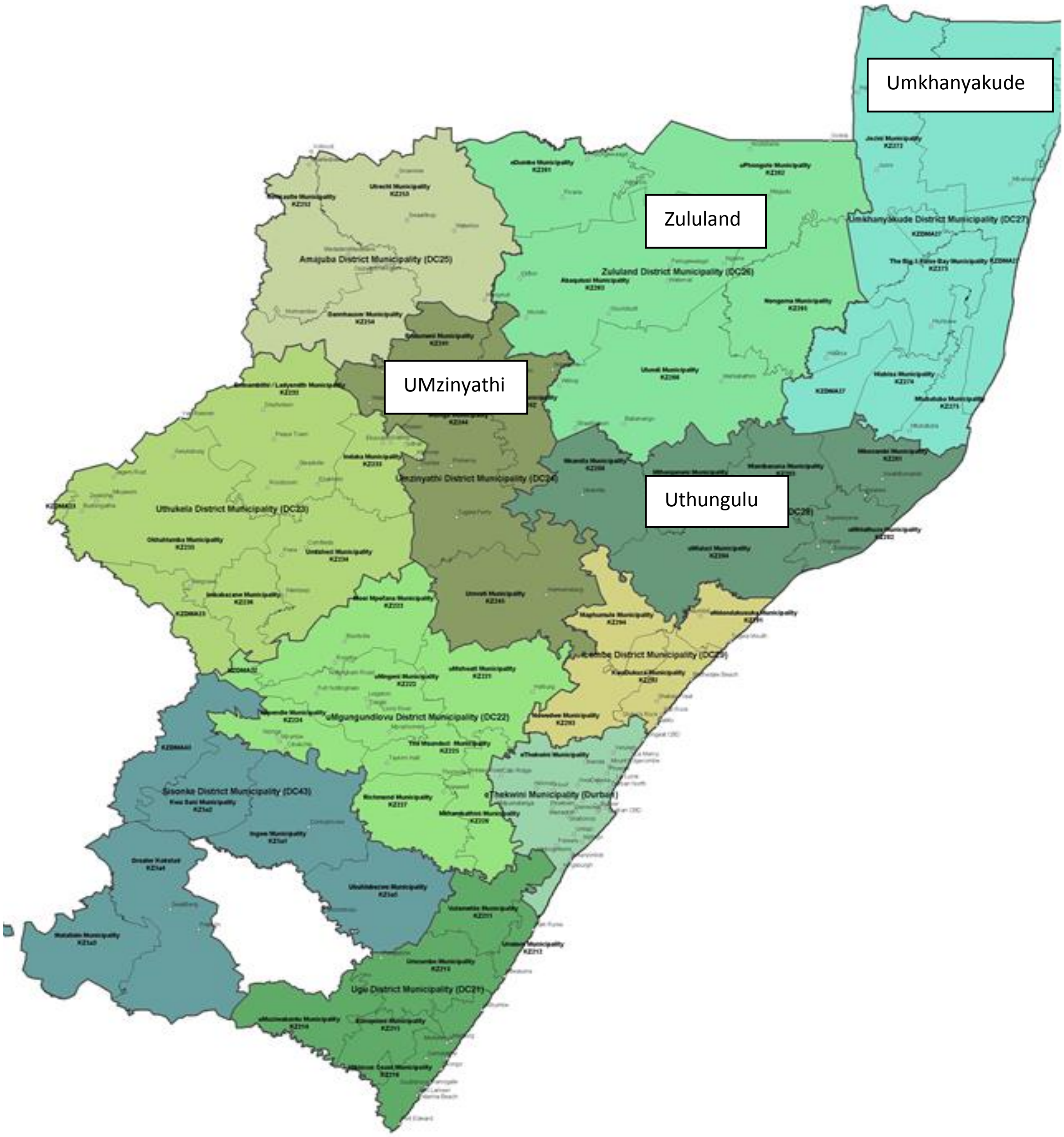


**Figure 4.1** Map of KwaZulu-Natal showing the areas in which the survey study was conducted (Umkhanyakude, Zululand, UMzinyathi, Uthungulu District municipalities)

*4.4.2 Field experiments*

Purposive sampling was used to select fields (Figure 4.2) on which controlled research using standard blocking techniques namely randomised complete block design (RCBD) on the effect of soil amendments on nutrient content of edible plant parts was conducted. Plant and soil samples were laboratory analysed using standard physico-chemical methods as appropriate. Data from controlled experiments were analysed using the GenStat statistical package and the Fishers Protected least significant difference was used for mean separation (Gomez and Gomez, 1984; Steel *et al*., 1997).

a b

**Figure 4.2** Some of the places at which some of the field and pot experiments were conducted; (a) an open field and (b) a polycarbonate roofed shelter.

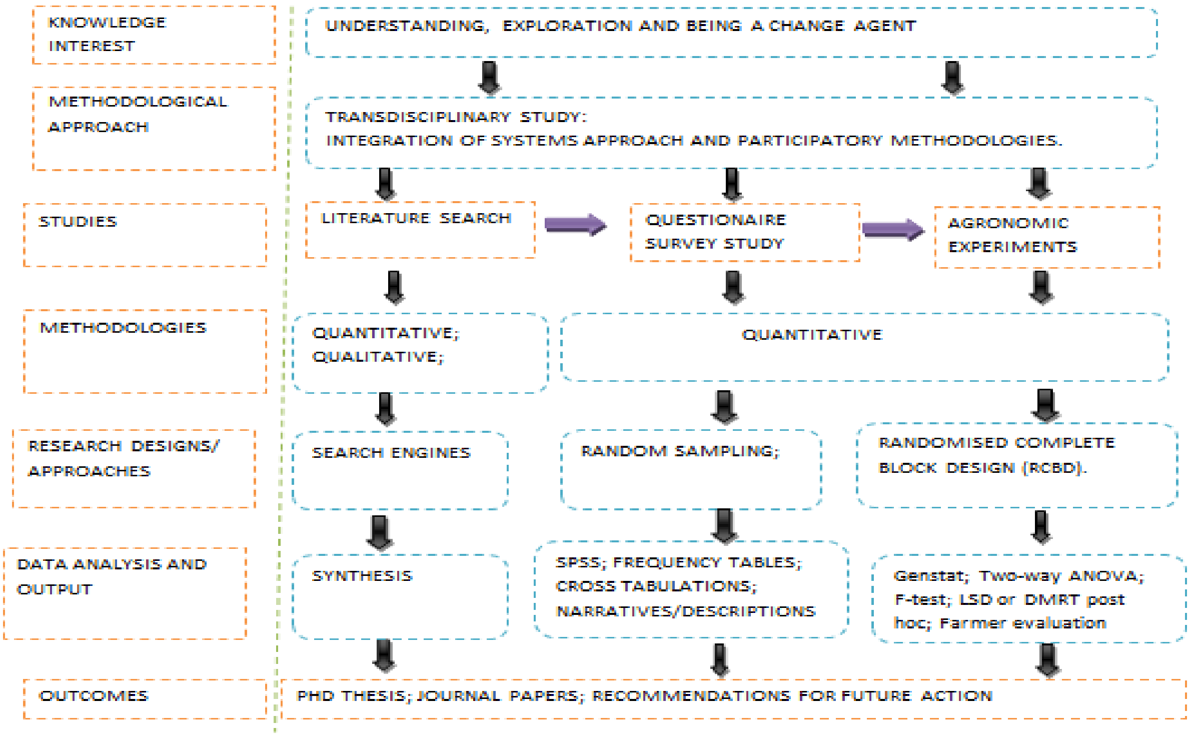


**Figure 4.3** Flow chart of the relationships between the methodologies employed in the study.

### 4.5 Dissemination of research results

The results of this study will be published as a thesis which will be freely available to the public online through the Stellenbosch University library. As indicated in Appendix 1some of the thesis chapters have already been published in online peer reviewed journals and are freely available. Results from this study will be summarised appropriately and made available to subsistence farmers through their agricultural extension officers who work directly with rural farmers, especially in northern KwaZulu-Natal where the study was conducted.

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# CHAPTER 5

## Survey on the utilization of wild vegetables in four districts of northern KwaZulu-Natal Province, South Africa[16]

### 5.1 Introduction

According to the National Census of 2001, KwaZulu Natal (KZN) province has the highest population (21.0%) in South Africa, with a GDP lower than the national average (Pauw, 2005; Mohamed, 2007). Agricultural households earn less than their non-agricultural counterparts, and poverty rates among this sector of the population were found to be very high (81.2%) compared to non-agricultural households (49.5%). Poverty rates vary between racial groups with the Africans (blacks) who constitute the bigger percentage of the population being the worst affected (poverty rate of 64.4 %). Poverty is more in rural areas (78.2%) than in urban areas (28.9%); therefore, hunger and malnutrition are still prevalent in many rural and urban areas (Pauw, 2005; van den Heever, 1995; Modi *et al.*, 2006).

A major cause of malnutrition has been found to be vitamin and trace element deficiencies; a phenomenon described as hidden hunger (Tisdale *et al.*, 1990). In the case of northern KZN, these affected people are living in areas rich in highly nutritious wild vegetables which not only provide abundant nutrients but also prevent and cure certain ailments. In sub Saharan Africa for instance, wild vegetables are important dietary components as they are used to prepare sauces and relish that accompany carbohydrate staples like *pap/phuthu* in South Africa, *sadza* in Zimbabwe, *fufu* in West Africa and *ugali* in east African countries. A previous study conducted in Ndunakazi, KZN, showed that 44% of pre-school and 52% of primary school children were vitamin A deficient (Faber and Benade, 2003). The study also revealed that the diet lacked variety whilst the intake of vitamin A and carotene rich foods was low. The diet mostly consisted *phutu* with legumes (mostly beans). Wild vegetables can bring variety, vitamins and other nutrients (Faber *et al.,* 2002; Faber and Benade, 2003). They are inexpensive yet high quality sources of nutrition

[16] This chapter was published in African Journal of Agricultural Research as Lewu, F.B and Mavengahama, S. 2011. Studies on the utilization of wild vegetables in four districts of northern KwaZulu-Natal Province, South Africa. African Journal of Agricultural Research Vol. 6 (17), pp. 4159 - 4165

especially for low income and marginalised sectors of the economy (Smith and Ezyaguirre, 2007). These vegetables are also believed to be medicinal. Common wild vegetables like *Amaranthus* spp, *Galinsoga parviflora*, *Tulbaghia violacea* have been evaluated at the University of KwaZulu Natal and have shown promise in the management of diseases like hypertension among others (Mackraj, 2007).

The cultivation of wild vegetables has declined drastically because of excessive cultivation of field crops, which includes chemical elimination of wild vegetables as they are considered as weeds (Odhav *et al.*, 2007; van Rensburg *et al*., 2007; Kwapata and Maliro, 1995; Lewu and Afolayan, 2009). They are underutilised in favour of non-native vegetables (Rubaihayo, 1992). Shackleton (2003) concluded that there was not enough importance attached to the value of wild plants in household food security by governments, extensionists and development planners.
The decline in the use of wild vegetables by many rural communities has resulted in poor diets and increased incidences of nutritional deficiencies (Smith and Ezyaguirre, 2007; Medisa and Tshamekang, 1995). Dietary utilisation of non-domesticated plants has received little research attention (Mauyo *et al.*, 2008) and this has led to a narrowing of the food base with attendant malnutrition. As a result there are many gaps in knowledge with respect to production requirements for wild vegetables. These gaps range from lack of germplasm from which genetic material for the development of new cultivars and improvement of current cultivars can be obtained, to lack of information on production practices (Smith and Ezyaguirre, 2007). The objective of this study was to gather information on the occurrence, extent of utilisation, cultivation and attitudes towards these vegetables in four districts of northern KwaZulu-Natal.

## 5.2 Materials and Methods

The research was conducted amongst the predominantly Zulu speaking people living in four districts of northern KwaZulu-Natal Province, South Africa. The surveys were conducted in selected villages in UMzinyathi, uMkhanyakude Uthungulu and Zululand district municipalities. The four districts selected for this study lie approximately within latitude 27$^{o}$ S and 29$^{o}$ S and longitude 30$^{o}$ E and 33$^{o}$ E (DEAT, 2000). The province of KwaZulu is characterized by diverse climatic conditions due to large variation in topographical features such as the altitude that ranges from sea level at the shoreline to over 3000 m at the western border along the Drakensberg Mountains. Rainfall ranges from 500 mm to over 1500 mm per annum (DEAT, 2000). The coastal region is associated with humid and warmer temperatures.

*The survey:* The study involved the use of Rapid Rural Appraisal technique based on a structured questionnaire to collect both quantitative and qualitative data (Marshall and Newton, 2003; Lewu, *et al*., 2007). One respondent was interviewed per household and a total of 99 respondents were interviewed individually. The survey was conducted over a period of two months (April – May 2009). Information collected included socio-demographic data (name, gender of household head, age, household size, household age, income, occupation); names of wild vegetables used; ecologies from which they were collected; plant parts eaten; preferences; vegetables used for medicinal purposes and propagation methods and conservation practices. Local names of collected vegetables were matched with scientific nomenclature following guidelines outlined by earlier workers (Flyman and Afolayan, 2006a; Modi *et al*, 2006; Odhav *et al*., 2007; Zobolo *et al*., 2008). Where the local names could not be matched with scientific names, only the local names have been presented. Being predominantly Zulu speaking communities, all questionnaires were administered in *isi*Zulu.

## 5.3 Results

Many aspects of traditional culture are still preserved in these former homeland areas and most of the inhabitants are mainly dependent on farming, natural resources and pension payments for subsistence. According to the socio-demographic data collected in this study household size ranged from one to 21 members. Thirty five percent of respondents were aged 60 years and above. Thirty nine percent had primary school education, 26% percent had secondary school education while 26 % never passed through western education. The socio-economic status of the respondents is presented in Table 5.1.

**Table 5.1** Socio-economic data of respondents from four districts in KwaZulu-Natal

| Attribute | Frequency | Percent |
|---|---|---|
| **Household size** | | |
| 1–3 | 9 | 9.0 |
| 4–7 | 46 | 46.5 |
| 8–9 | 16 | 16.2 |
| 10–13 | 14 | 14.1 |
| >13 | 9 | 9.1 |
| **Employment status of household head** | | |
| Not employed but on pension | 35 | 35.4 |
| Not employed not on pension | 21 | 21.2 |
| Self employed | 6 | 6.1 |
| Vegetable vendor | 5 | 5.1 |
| Employed (wage salary earner) | 32 | 32.3 |
| **Income** | | |
| No income | 11 | 11.1 |
| Not disclosed | 9 | 9.1 |
| R100–R500 (US$13–67) | 8 | 8.1 |
| R501–R1000 (US$68–133) | 24 | 24.2 |
| R1001–R2000 (US$134–268) | 24 | 24.2 |
| R2001–R3000 (US$269–667) | 3 | 3.0 |
| >R3000 (>US$667) | 20 | 20.1 |

*5.3.1 Access to wild vegetables*

*5.3.1.1Diversity of wild vegetables utilised*

The collective name for wild vegetables across all the districts is *imfino.* The study also noted that the name *imfino* is also used to identify domesticated green leafy vegetables like pumpkins (*Cucurbita* spp) and cowpea (*Vigna unguiculata*). Ninety eight of the respondents utilise wild vegetables mainly as a relish and for medicinal purposes as well. The majority of respondents (62%) indicated that they utilise the first seven vegetables listed in Table 5.2, whilst the most commonly preferred being imbuya (*Amaranthus* spp) (representing 78% of the respondents interviewed) followed by *uqadolo* and *imbilikicana.*

**Table 5.2** Use of wild plants as food and medicines in selected villages in UMzinyathi, UMkhanyakude, Uthungulu and Zululand districts, northern KwaZulu-Natal

| Vegetable eaten | Plant part eaten | Medicinal | Ailments treated |
|---|---|---|---|
| Imbuya *(Amaranthus spp)* | leaves | Not mentioned | |
| *Imbilikicana (Chenopodium album)* | leaves | Yes | Diarrhoea |
| *Uqadolo (Bidens pilosa)* | leaves | Yes | Stomach aches, influenza |
| Isishukelana *(Galinsoga parviflora)* | leaves | Not mentioned | |
| *Intsungu (Mormodica foetida)* | leaves | Yes | High blood pressure, diabetes |
| *Imbati* (*Urtica dioica or urens*) | leaves | Yes | Headaches |
| *Umsobo Solanum nigrum* | leaves | Not mentioned | |
| *Intebe* | leaves | Not mentioned | |
| *Umayebabo* | leaves | Not mentioned | |
| *Uvovo* | leaves | Yes | Coughing |
| *Inkalane* | leaves | Yes | Coughing, diarrhoea, cleaning digestive system |
| *Amasosha* | leaves | Yes | Diarrhoea, vomiting, stomach aches |

In addition to those in Table 5.2, the following plant species were also mentioned as vegetables but are utilised on a smaller scale: *amakhowe, ikabekabe, izigagane, umsashane*. An interesting aspect of the findings was that various vegetables species are mixed for consumption; a practice respondents reported improves the taste of the relish.

*5.3.1.2 Medicinal uses of wild vegetables*

Some of the vegetables are used as medicines for the treatment, prevention or management of various ailments. For instance, *intsungu* (*Mormodica foetida)* was the most cited as a medicine and is used mostly to manage high blood pressure as indicated by 37% of respondents. However, the survey revealed almost all of the wild vegetables are believed to have some form of medicinal and therapeutic properties when compared with exotic vegetables and as such there is no formal categorisation into medicines and vegetables.

*5.3.1.3 Method of acquisition of wild vegetables and frequency of collection*

The majority of respondents (81%) gathered vegetables which grow as weeds or volunteer crops in their fields and home gardens as well as the veldt and the mountains. (Figure 5.1) Ten percent indicated they buy and 8% both collected and bought depending on availability.

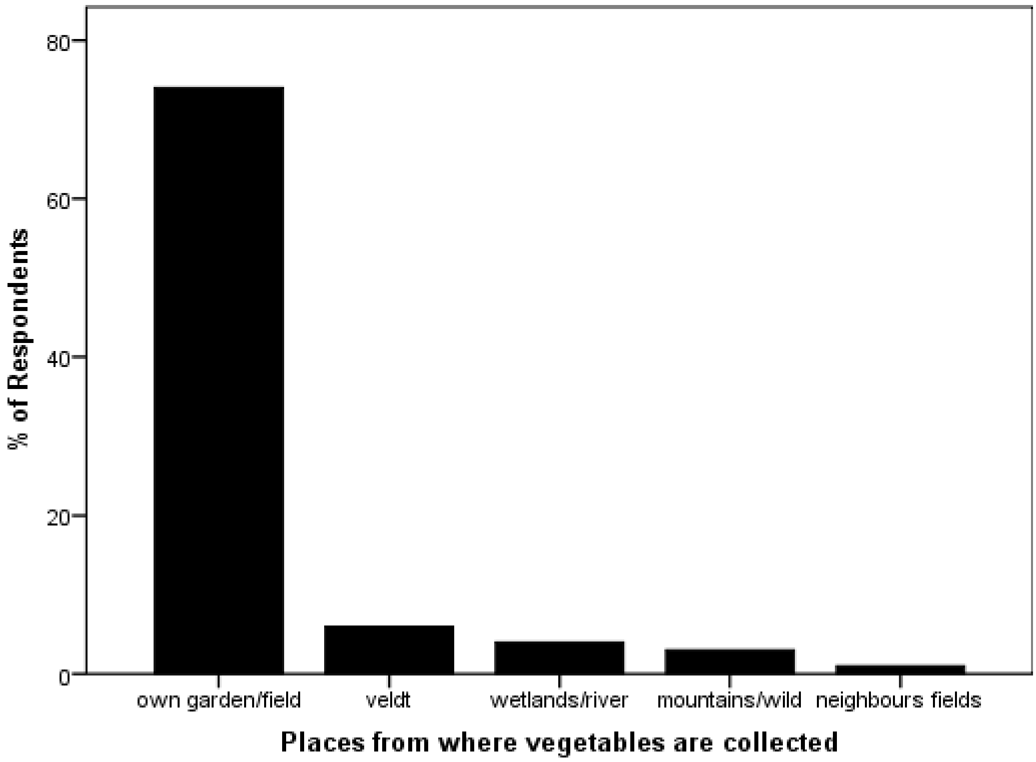


**Figure 5.1** Places where respondents collected wild vegetables in the studied communities in northern KwaZulu-Natal.

Whilst most respondents indicated that they harvested leaves, obtaining information on the frequency and volume of harvesting was not possible as respondents do not measure the amounts of these wild vegetables. As a result daily, weekly, monthly and yearly consumption patterns and estimates could not be established through this survey. Collection does not follow a regular pattern as the survey revealed that people consumed more when the vegetables were available.

*5.3.1.4 Place and season of wild vegetable collection*

Vegetables are gathered from various habitats. Seventy four percent of respondents collected from their own cultivated fields, gardens and homesteads (disturbed land) (Figure 5.1) with some indicating that they harvest from neighbours fields when they could not harvest enough from their own, perhaps suggesting that the population of these vegetables may be declining. Forty one percent indicated that they collect vegetables all year round specifically from their fields and gardens during summer and from wetlands and gardens during off-season. They also indicated that some vegetables are available only in summer while a few are available all year round.

### *5.3.2 Cultivation of wild vegetables*

Seventy six percent of respondents do not cultivate wild vegetables; while 22% who indicated that they cultivated grew *izintanga* (pumpkins – *Cucurbita* spp), which although referred to as *imfino*, are not wild vegetables. None of the respondents kept seed of the wild vegetables. Various responses were given on the conservation effort of wild vegetables in the study area. Fifty three percent of respondents observed that wild vegetables occur as weeds on their cultivated land and believe seeds of these species are stimulated to germinate by land cultivation.

### *5.3.4 Attitudes towards wild and exotic vegetables*

Ninety eight percent of respondents utilise cabbage as relish, however, 76% preferred wild vegetables to cabbage if they were readily available. Among other reasons, respondents preferred wild vegetables to cabbage because it was believed that cabbage 'causes disease', it is expensive, requires inputs to cultivate, has a disagreeable smell, is not delicious and requires food additives to taste good. Respondents further reported that wild vegetables are free, easy to cook, and could taste well even without cooking oil and food additives. They also claimed that wild vegetables are highly nutritious, and prevent and cure some diseases.

### *5.3.5 Quantities consumed and trade in wild vegetables*

A small proportion of respondents (7%) indicated that they sell wild vegetables. However, they did not quantify the amount harvested as no records are kept but some gave an estimate of the income accruing from the selling of the vegetables ranging from R100 to R400 per annum.

## 5.4 Discussion

This study revealed that people in the study area utilise wild vegetables mostly as a relish. Most people gather the vegetables from the wild and those who indicated that they do cultivate *imfino* identified *Cucurbita spp* and *Vigna unguiculata* as the cultivated species. Although these species are known as *imfino*, they are not gathered from the wild as they are already domesticated. The local taxonomy of wild vegetables varies as was also reported by Jansen van Rensburg *et al.* (2007). For instance, in Melmoth (northern KwaZulu-Natal) we noted that respondents identified *Bidens pilosa* as *imfino* yet in other villages it is known as *uqadolo* and the name *imfino* is a collective term for all wild vegetables. This suggests that local nomenclature/taxonomy of the same species varies from place to place or between communities in the same locality. It is important that wild vegetables are correctly identified by their botanical and local names. This characterisation provides the basis for identifying the variation in nutrients and health protecting traits among cultivars within a species (Smith and Ezyaguirre, 2007).

The major part of the vegetables consumed by respondents is leaves; although some occasionally harvest roots and tender stems. Young growing points (shoots) have also been observed to be harvested (Jansen van Rensburg *et al.*, 2007). The consumption pattern of the vegetables shows that more vegetables are consumed in summer compared to winter season. The major reason for this difference has been suggested to be the relative availability of wild vegetables in summer than in winter. This finding is similar to an earlier study by Shackleton (2003) who reported that consumption in winter was less than in summer. Based on the current study, the collection pattern indicates that the vegetables are in demand all year round and that consumption is only limited by availability. Certain difficult circumstances like famine also cause the consumption of other wild plants which are not ordinarily consumed vegetables. Flyman and Afolayan (2006b) and Odhav *et al.* (2007) reported that certain wild vegetables were consumed only during scarcity and famine. A study by Modi *et al*. (2006) at Ezigeni, KwaZulu –Natal revealed that the availability of wild vegetables suddenly declined in May and became scarce between July and August and only increased as the season progressed from August to October. The sudden manner in which these vegetables become unavailable leaves many vulnerable families exposed to hunger between the months of May to November. In a study in Limpopo province, Dovie *et al*. (2007) found out that wild edible herbs within the homesteads were tightly controlled by the corresponding household, although some allowed other households to harvest them from time to time depending on how they related to one another. Some are collected from the veldt, wetlands and woodlands and mountains. The aforementioned findings suggest the need to be able to make these wild vegetables available during the off-season months. This could be achieved through cultivation of these vegetables at home so that families have greater control of the availability rather relying on natural and mostly unpredictable availability.

Jansen van Rensburg *et al*. (2007) noted that women are the more involved in the preservation of wild vegetables. They select them and leave them undisturbed during weeding. Some communal farmers are also aware of the relationship between animal manure application and the proliferation of wild vegetables. This was revealed by the respondents (4%) who said they applied manure to stimulate the growth of the wild vegetables. Ninety percent gather these vegetables within 2 km from their homesteads and they collect them from the same place every year, perhaps indicating that the populations of these wild vegetables are not increasing or spreading beyond their natural habitats. Respondents observed that the amounts of wild vegetables varied directly with seasonal rainfall; with the tendency of increased growth and increased plant numbers during the rainfall season. However the population dynamics of the species is not well understood by the respondents. In the study by Dovie *et al*. (2007) in Limpopo, 79% of respondents perceived wild vegetables to be less available than in previous decades in terms of both amount and species diversity.

Studies on wild vegetables by other researchers also suggest that women are the major participants in the gathering of wild vegetables (Vorster *et al.*, 2007; Jansen van Rensburg *et al.,* 2007). This current study revealed that youths were not willing to harvest or consume wild vegetables. Respondents gave several reasons for the unwillingness of youths to consume wild vegetables. One reason was that collecting wild vegetables is time consuming, as confirmed by empirical studies in the Eastern Cape by Shackleton (2003) who found out that harvesting time ranged from 2 hours 30 minutes per week at one locality and 3 hours 45 minutes per week in another locality. The amount of vegetables gathered was however, not indicated.

While the youths believe that gathering of wild vegetables was a special preserve for the poor and old, the elders in the community reported that youth are lazy and do not have enough knowledge of wild species; with the tendency of mixing wild vegetables with poisonous species (e.g. *iloyi*)

Some previous studies have been able to quantify the frequency of utilisation (Nesamvuni *et al*., 2001; Steyn *et al*., 2001; Shackleton, 2003). Shackleton (2003) used empirical methods and quantified the amount of vegetables consumed at KwaJobe in KwaZulu-Natal and found this to range from 76.9 kg to 108.5 kg per household per annum; with a farm gate price of R2.65 per kg. The study by Nesamvuni *et al.* (2001) indicated servings of 180 to 270 g consumed once a week while in their study Dovie *et al*. (2007) estimated consumption to be at 15.4 ± 2.5 kg per household per annum; with a gross monetary value of $182.9 ±33.1 per household per annum.

**5.5 Conclusions**

Wild vegetables play an important role in the daily lives of most rural people in northern KwaZulu – Natal. They are widely consumed as a relish although they are not being cultivated; their method of acquisition being gathering from homesteads, cultivated lands, the veldt and woodlands. These vegetables are also believed to be medicinal, although there is variability in the knowledge of the ailments treated. The local taxonomy or naming of these vegetables varies among villages in the same district such that a vegetable in one village is assigned to a different species of vegetable in another village. Wild vegetables are abundantly available during summer and there is a decrease, even no-availability, during winter and the dry season leaving some vulnerable people who rely on them in a state of food deficit and shortage. There is need for domestication and cultivation of wild vegetables to ensure a continuous and regular availability of these species throughout the year.

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# CHAPTER 6

## Comparative trace element composition of two wild vegetable species in response to soil applied micronutrient fertiliser[17].

### 6.1 Introduction

A review of trace elements in food in South Africa and other developing countries by Steyn and Herselman (2005) revealed widespread shortages. They concluded that the poor micronutrient status among the poor is caused by insufficient and undiversified diets and compounded by soils of low micronutrient status. There are three main ways in which micronutrients can be added to foods, namely, food fortification or supplementation, genetic bio-fortification and agronomic bio-fortification (White and Broadly, 2009). Food fortification is widespread and efficient for those who can afford the fortified foods, but is not applicable to most rural populations in Africa, who produce most of their staple crops, vegetables and meat at their farms and therefore do not generally purchase micronutrient supplemented foods. Genetic bio-fortification is still mostly at the experimental stage and even when it becomes viable, it might be some time before the genotypes that result are widely available and affordable to subsistence farmers. Agronomic bio-fortification, which is the increase in plant tissue micronutrient content through soil or foliar application as fertilisers, also involves the purchase of these mineral fertilisers and is only viable in commercial agriculture. Another strategy, which is the long-term goal of our present study, is to use locally available wild, semi-domesticated and domesticated vegetable species that have the ability to concentrate the mineral micronutrients zinc (Zn), copper (Cu) and iron (Fe) even from depleted soils.

Our targeting of wild vegetables (WV) is based on the knowledge that they are widely available and relatively easily accessible to poor subsistence farmers. These wild vegetables (also known in South Africa as African leafy vegetables, indigenous vegetables, *morogo* and *imfino*) are variously reported to be superior to

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conventionally cultivated vegetables such as Swiss chard (*Beta vulgaris* var. cicla) and cabbage (*Brassica oleracea* var. capitata) (Oelofse and van Averbeke, 2012; Flyman and Afolayan, 2006) in micronutrients, including beta-carotene, and minerals such as zinc (Zn), iron (Fe) and copper (Cu). These vegetables are important to the subsistence farmers, especially the poor, some of whom rely on WV as a major form of relish used to complement and accompany staple meals such as phutu, pap, ugali and sadza (Mavengahama *et al*., 2013)

A recent report (2012) on the importance of African leafy vegetables re-affirmed the potential of these vegetables in the eradication of micronutrient under-nutrition (Oelofse and van Averbeke, 2012). The report particularly highlighted the prevalence of vitamin A and iron deficiencies in rural parts of South Africa. Although Zn deficiency was reported as not being well documented in developing countries (Rosado, 2003) including South Africa (Oelofse and van Averbeke, 2012, the World Health Organisation (WHO) has identified zinc as one of the most serious deficiencies in the past decade (FAO, 2009). The consumption of fruits and micronutrient-rich vegetables has been reported to low, leading to monotonous and micronutrient-poor diets in several provinces of South Africa (Labadarios *et al*., 2011; Oelofse and van Averbeke, 2012). It is against such a background that promotional and research efforts for wild vegetables need to be taken seriously especially among the poor.

Wild vegetables are widely reported to have superior nutritional properties with respect to micronutrients compared to conventional vegetables such as cabbage (*Brassica oleracea* var. capitata) and Swiss chard (e.g. van der Walt *et al*., 2009; Ndlovu and Afolayan, 2008; Nesamvuni, *et al*., 2001; Steyn *et al*., 2001; Odhav *et al*., 2007). There is wide variability in the nutritional composition reported for these vegetables in different studies. The claim that uncultivated indigenous vegetables could have superior micronutrient levels to cultivated conventional vegetables suggests that there is the possibility of increasing their micronutrient content if they are supplied with micronutrients added to the soil (as alluded to by Nube and Voortman, 2006. For most conventional crops, research has established critical points for deficiency or excess (toxicity). Such information is important in crop production if correct amounts of fertilisers are to be applied. The levels of nutrients applied in crop production also determine the ability of a food crop to supply nutrients to humans. Deficiencies of these micronutrients in the soil also lead to reduced crop yields, thereby presenting a double problem of reduced food of poor nutritional quality (Nube and Voortman, 2006). Some studies that reported the superior nutrient composition of wild vegetables in South Africa (e.g. van der Walt *et al*., 2009; Ndlovu and Afolayan, 2008; Nesamvuni, *et al*., 2001; Steyn *et al*., 2001; Odhav *et al*., 2007) were not controlled experiments and involved collection from the wild or purchasing from the market and conducting tests. The aim of the present study was to compare, under well-defined conditions, the accumulation of Zn, Cu, and Fe in leaves of two leafy wild vegetable species commonly consumed in the rural areas of South Africa and a reference vegetable crop that is also widely eaten.

## 6.2 Materials and methods

The experiment was conducted on potted plants in a greenhouse at the University of Zululand (28$^{o}$51'S; 31$^{o}$51'E). The growing medium used was a Glenrosa soil (Mulder, 1988). The soil was sieved through mesh wire to remove large stones, clods and sticks.

### *6.2.1 Treatments*

We investigated three vegetable species namely *Corchorus olitorius*; *Amaranthus sp.* and Swiss chard. The three micronutrients tested were Fe, Cu and Zn, each of which was applied at 0, 5, 10 or 15 kg/ha as sulphate salt (Table 6.1). The treatments were arranged in a factorial experiment that was laid out in a completely randomised block design with three replications.

### *6.2.2 Fertilizer application*

Fertilizer application rates were calculated per plant based on a standardised plant density of 100 000 plants per hectare. To facilitate application of the minute quantities of micronutrient fertiliser used, amounts of the micronutrients for each rate (9 treatments per rate) were mixed, dissolved in de-ionised water and made up to 36 ml, and then applied as a 4 ml solution to the soil. A blanket basal fertiliser of 5 g per plant of NPK 2:3:2 (14) was applied pre-plant to all pots. Lime ammonium nitrate (LAN, 28% N) fertiliser was also applied post-emergence to all pots at a rate of 3 g per plant.

*6.2.3 Plant management*

Seedlings of each of the three test species were germinated and grown for 38 days in a commercial growth medium (Hygromix®) in polystyrene trays and transplanted to potted soil containing the basal fertiliser of 5 g per plant of NPK 2:3:2 (14). One seedling was planted per pot in 2.5 kg of soil. The micronutrients were added 15 days after transplanting. Thereafter, plants were watered in a way that avoided leaching of the nutrients from the soil. Samples of the youngest fully expanded leaves (blade and petiole) were taken 26 days after the application of micronutrients for chemical analysis.

**Table 6.1** Micronutrient fertilizer combinations and application rates

| Micronutrient element rate equivalent (kg/ha | Micronutrient element rate per plant per pot (g) | | |
|---|---|---|---|
| | Zn | Cu | Fe |
| 0 | 0 | 0 | 0 |
| 5 | 0.22 | 0.25 | 0.20 |
| 10 | 0.44 | 0.50. | 0.40 |
| 15 | 0.66 | 0.75 | 0.60 |

*6.2.4 Chemical analyses of youngest fully expanded leaves*

Plant analysis was conducted by the Fertiliser Advisory Services of the South African Sugar Research Institute (SASRI), Mount Edgecombe.

*6.2.4.1 Measurement of Cu, Zn, Fe Mn and S.*

For Zn, Cu, Fe, Mn and S a one gram leaf sample was digested in 15 ml nitric acid followed by 5 ml perchloric acid. After digestion, the resultant mixture was filtered and then made up to 50 ml using water. The elements were then determined using atomic absorption (AA) spectrophotometry. Sulphur was determined colourimetrically.

*6.2.4.2 Measurement of N, P, K, Ca and Mg*

For N, P, K, Ca and Mg a 0.25 g sample was digested in 2 ml selenised sulphuric acid for 1.5 hours in a Kjeldatherm block digester at a temperature of 370 $^{o}$C. After digestion, the samples were diluted to volume with water and K, Ca and Mg were determined by AA; N and P were determined colourimetrically.

*6.2.5 Soil analyses*

Information on physico-chemical attributes of the soil (Appendix 3) was obtained prior to fertilizer application. Soil pH was determined in $CaCl_2$. Exchangeable acidity was determined by titration after extraction with 1 M potassium chloride. The macronutrients P, K, Ca, Mg and Ca and micronutrients Fe, Cu, Zn and Mn were determined by the method described by van der Merwe *et al*., (1984) after extraction with the Ambic–2 extraction method using EDTA-di-ammonium solution. Truog-extractable P was determined colourimetrically after extraction with 0.02 N sulphuric acid. Silicon was determined as described by Miles *et al*., (2011) after overnight extraction with 0.01 M calcium chloride.

*6.2.6 Data analysis.*

Analysis of variance (ANOVA) was performed on the data using the Genstat 12 statistical package to test for significant treatment effects. Statistical significance was evaluated at $p < 0.05$; where the F-tests were significant the treatment means were separated using the least significant difference (LSD) test (Steel *et al*, 1997; Gomez and Gomez, 1984).

**6.3. Results and discussion**

There were significant differences in the concentrations to which the three vegetable species accumulated the micronutrients Fe, Zn, Cu and Mn (Table 6.2). Swiss chard accumulated Cu, Zn and Mn in the leaves significantly ($p<0.01$) more than *Amaranthus sp.* and C. *olitorius* (Table 6.2). The variations between the vegetables in these three micronutrients were greater for Zn (72–363 ppm) and Mn (98–286 ppm) than they were for Cu (9–14 ppm). C*. olitorius* had the least capacity to concentrate Mn and Zn in the leaf, which suggested that this vegetable is a less satisfactory candidate for agronomic bio-fortification of these micronutrients. However, C*. olitorius* leaves accumulated Fe at significantly higher concentration (327 ppm) than did *Amaranthus* sp*.* (222 ppm) or Swiss chard *(*295 ppm). Sulphur as a macro-nutrient varied among the plant species tested. The mean S concentration in the leaves ranged from 0.26% in *C. olitorius* to 0.34% in *Amaranthus* sp. and Swiss chard (Table 6.4).

**Table 6.2** The main effects of vegetable plant species on mean leaf concentrations of Cu, Fe, Zn and Mn; data are means of three replications

| | Concentration (ppm) | | | |
|---|---|---|---|---|
| | Cu | Fe | Zn | Mn |
| **Vegetable** | | | | |
| *Corchorus olitorius* | 9.2 | 327 | 72 | 97.9 |
| *Amaranthus* sp. | 8.8 | 222 | 235 | 199.8 |
| *Beta vulgaris* var. cicla | 14.3 | 295 | 363 | 285.8 |
| Significance | ** | * | ** | ** |
| $LSD_{(0.05)}$ | 2.4 | 70 | 63 | 28.9 |

The effects of fertilizer application rate on leaf nutrient concentration differed according to nutrient and also with the plant species. For the pooled data of the three plant species, leaf Fe and Mn concentrations did not respond to incremental Fe application to the soil. Although leaf Cu, Zn and S increased with increasing application rate, they did so within narrow ranges and the responses were generally greater with the low increments (5 kg/ha) than they were with larger additions (Table 6.3). The narrow variation ranges implied that the concentrations of the nutrients in the plants are strictly controlled. However, in a previous study in which Swiss chard was grown in several different types of soil in South Africa (Steyn and Herselman, 2005), variations in micronutrient concentrations ranged between 2.72–152.12 and 11.9–623.8 mg/kg for Cu and Zn, respectively. In the same study Swiss chard samples from fruit and vegetable markets and shops had Cu and Zn levels that ranged from 9.4–111.7 and 34.0–816.0 mg/kg respectively (Steyn and Herselman, 2005). The large discrepancies between our study and that of Steyn and Herselman (2005) in leaf Cu and Zn concentration ranges of Swiss chard are difficult to explain.

**Table 6.3** The main effects of fertilizer application rate on pooled mean leaf concentrations of *Beta vulgaris* var. cicla; *C. olitorius* and *Amaranthus* sp.; data are means of three determinations

| | Concentration (ppm) | | | |
|---|---|---|---|---|
| | Cu | Fe | Zn | Mn |
| Mineral element amount (kg/ha) | | | | |
| 0 | 4.69 | 280 | 60 | 192.6 |
| 5 | 9.27 | 274 | 218 | 202.2 |
| 10 | 14.75 | 312 | 277 | 177.5 |
| 15 | 14.49 | 258 | 338 | 205.9 |
| Significance | ** | ns | ** | ns |
| $LSD_{(0.05)}$ | 2.80 | - | 72 | - |

ns, not significant; ** significant at p<0.01; * significant at p<0.05.

¥ Minerals were applied as a mixture of sulphates of Cu, Fe and Zn to give equal proportions of elements for a given rate.

There were significant interactions between plant species and fertilizer rate in terms of leaf Zn and Cu. In all three vegetables, the leaf Cu concentration levels increased with Cu addition up to 10 kg/ha but declined at 15 kg/ha (Figure 6.1). The decline in leaf Cu concentration at 15 kg/ha Cu was more marked in C*. olitorius* than in Swiss chard and *Amaranthus* sp. The reason for the decline in uptake at high application rates is not known.

Swiss chard accumulated more Zn and Cu at all fertilizer application rates (Fig. 6.1 and 6.2), which contradicted our hypothesis that wild vegetables have a greater inherent ability to accumulate micronutrients from the soil than the widely cultivated exotic vegetables. Nonetheless, the wild vegetables also responded positively to the incremental application of the two micronutrients, which supported our postulate that the addition of micronutrients would result in increased micronutrient levels in WV leaves. Thus, when the vegetables are grown in soil with augmented micronutrient content, they will assimilate increased quantities from the soil up to a certain threshold.

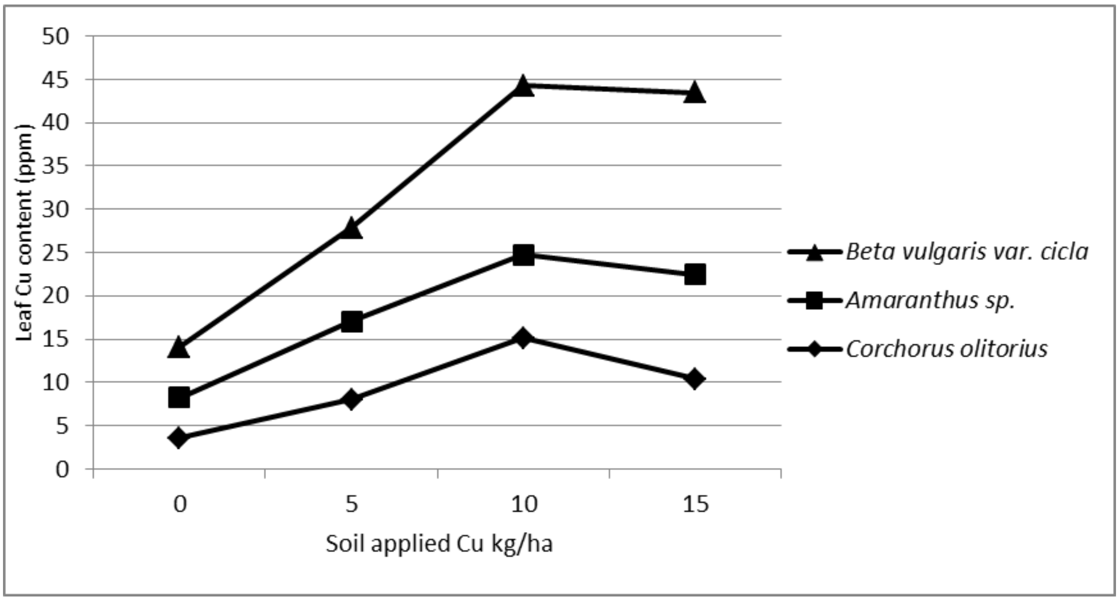


**Figure 6.1** Leaf Cu content of the three vegetables tested in relation to Cu augmentation of soil growth medium

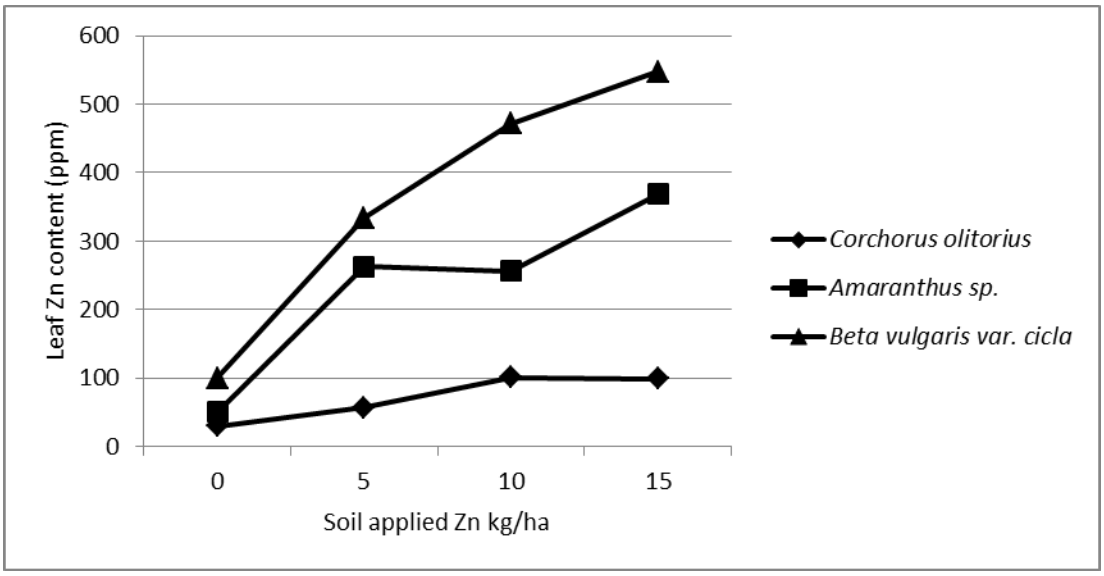


**Figure 6.2** Leaf Zn content of the three vegetables tested in relation to Zn augmentation of soil growth medium.

The application of micronutrient fertilizers did not affect the concentration of macronutrients Ca, K, Mg, P and N (not shown), but significantly there were differences between the plant species tested in the concentration of Ca, Mg and P and S (Table 6.4). Between the three plant species tested, C. *olitorius* had the highest Ca concentration in the leaves but was associated with markedly lower corresponding concentrations of Mg and P in the leaves. However, a regression analysis of this negative relationship showed that it was not significant.

**Table 6.4** Macronutrient composition of three vegetable species in response to micronutrient fertiliser added to soil

| | Concentration (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | Ca | K | Mg | P | N | S |
| Vegetable | | | | | | |
| *Corchorus olitorius* | 1.77 | 3.15 | 0.303 | 0.354 | 3.864 | 0.266 |
| *Amaranthus* sp. | 1.37 | 3.33 | 1.012 | 0.511 | 3.796 | 0.344 |
| *Beta vulgaris* var. cicla | 0.55 | 3.50 | 1.041 | 0.614 | 3.843 | 0.343 |
| Significance | * | ns | ** | ** | ns | ** |
| $LSD_{(0.05)}$ | 0.83 | - | 0.079 | 0.09 | - | 0.054 |

ns, not significant; ** significant at $p<0.01$; * significant at $p<0.05$.

The levels of micronutrients tested in this study could be considered high or even toxic to crops. We did not evaluate toxicity in this study, but observed no visible toxicity symptoms. The levels of micronutrients obtained from the leaf analysis results after applying micronutrient fertiliser were much higher than those reported for WV collected from the wild (Nesamvuni *et al*., 2001; Steyn *et al*., 2001; Odhav *et al*., 2007; Ndlovu and Afolayan, 2008; van der Walt *et al*., 2009). However, not all micronutrients present in crops are available for uptake by humans and there is need to investigate if the increase in leaf micronutrient level has a positive effect on bioavailability of the micronutrients in wild vegetables. Micronutrients are generally applied in minute quantities (Fertilizer Society of South Africa, 2007), but mostly in commercial agriculture. Hence there is a danger of accumulation of micronutrients to toxic levels in the soil associated with high application rates of micronutrient fertilizers; hence the accumulation of micronutrients in soil treated with micronutrient fertilisers also needs to be assessed. The nutrient content of most soils in the subsistence farming sector is generally not well known, yet there is a belief among agriculturalists that micronutrients occurring naturally in the soil are adequate. In contrast, in commercial agriculture, where the nutrient status of soils is well known, farmers periodically apply micronutrients either as foliar sprays or chelates to soils.

## 6.4. Conclusions

The different vegetables species investigated demonstrated different abilities to take up Cu and Zn in the order Swiss chard > *Amaranthus* sp.> C. *olitorius*, and that they responded to soil applied micronutrients by taking up more from the soil as more was supplied but up to a certain point. Thus there was variable uptake of elements by the species. These variations in mineral composition show that each vegetable has a role to play in the diet as no single vegetable proved to be superior in all mineral elements. Our results are at variance with the currently held claim that wild vegetables have superior micronutrient content to exotic vegetable species. This reinforces the call for increasing dietary diversity as one of the ways to combat diet that lack micronutrients. A wide vegetable diet would ensure the foodstuffs complement each other in providing the necessary nutrients.

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# CHAPTER 7

## Effect of basal and top dressing soil amendments on yield of wild okra (*Corchorus olitorius*) in northern KwaZulu-Natal[18].

### 7.1 Introduction

The consumption of wild vegetable species is increasingly being promoted in various parts of the world including South Africa. Since these species are wild or semi-domesticated, their promotion in South Africa and other African countries necessitates agronomic research on the response of such species to fertilisers in terms of yield performance and mineral nutrients composition. The use of soil amendments in domesticated crops is well researched and documented worldwide. There is however a paucity of information on the requirements and responses to soil amendments for semi-domesticated and wild vegetables species especially in Southern Africa. In South Africa, studies on the effect of different types and rates of fertilisers on the yield and chemical composition of wild okra are still limited. However, in other parts of Africa (Nigeria), considerable studies on the response of Corchorus to the application of soil amendments have been conducted (e.g. Olaleye, 2008; Makinde *et al*., 2011; Musa *et al*., 2010; Olaniyi and Ajibola, 2008; Nwangburuka *et al*., 2012). In the study by Makinde *et al*., (2011) C. olitorius responded differently to different fertilisers. NPK mineral fertiliser resulted in higher moisture content; poultry manure resulted in highest mineral uptake while urea resulted in highest dry matter, suggesting perhaps that the source of nitrogen might affect C. *olitorius* growth.

In other wild vegetable species, the application of mineral nitrogen significantly increased leaf number per plant in *Solanum macrocarpon* (Olaniyan *et al*, 2006); *Cleome gynandra* (Mauyo *et al.*, 2008) and *Amaranthus hybridus* (Materechera and Medupe, 2006). In a study by Mhlontlo *et al* (2007), sheep kraal manure significantly increased the vegetative parts and grain yield of an *Amaranthus* species in the

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Eastern Cape Province, South Africa. Organic fertiliser has also been shown to affect the growth of indigenous vegetables (Masarirambi, *et al.*, 2012). In the study by Mhlontlo *et al* (2007), *Amaranthus* plant height, number of leaves and stem girth, significantly increased with increasing rate of application of sheep kraal manure. A similar study in Nigeria showed that cassava peel compost improved the yield and nutritional content of *Celosia argentea* L. (Akanbi *et al.*, 2007).

This current study is one of a series of studies aimed at contributing to the knowledge on the growth and yield responses of wild vegetables to different soil amendments. The knowledge would be to used inform future studies and develop agronomic recommendations for the cultivation of the vegetables. The specific objective of this study was to investigate the response of C. *olitorius* to a combination of different types of basal fertilisers and several rates of nitrogen top dressing.

### 7.2 Materials and methods

The experiment was conducted in polythene pots under a poly-carbonate roofed structure with open sides at the University of Zululand main campus at KwaDlangezwa (lat. 28°51'S; long. 31°51'E). There were two factors namely basal soil amendment and nitrogen top dressing. Basal soil amendments had three levels as follows: no soil amendment (control) (B1), cattle manure at 5 000 kg/ha (B2) and mineral (NPK) fertiliser (2:3:2(22)) at 500 kg/ha (B2). Nitrogen fertiliser had four levels: 0 kg/ha; 100 kg/ha; 200 kg/ha and 300 kg/ha lime ammonium nitrate (LAN) (28% nitrogen) applied as a 50:50 split. This was a 3 x 4 factorial resulting in 12 treatments which were arranged in a randomised complete block design with three replications. Each treatment had three plants and measurements taken were means of the three plants. All measurements were taken on the day of harvesting. Basal fertiliser treatments were spot applied 5 cm below the soil before planting. Several seeds were then directly planted a few millimetres below the soil. The seed used in this study was obtained from the Agricultural Research Council of South Africa. The plants were watered using rain water and each treatment received the same amount of water. Sowing was done on 16 September 2012. Germination commenced three days after planting. Thinning was done three weeks after planting (WAT) to leave one plant per pot. The first split of nitrogen was applied on 20 October and the second split was applied on 3 November 2012. Harvesting was done once off on 21 November 2012 before flowering. Some studies have that delaying the harvesting of C. *olitorius* until after reproductive growth results in reduced amounts of some micronutrients such as copper (e.g. Musa *et al*., 2010). The marketable yield consisted of leaf and petioles and tender shoots and stems. Plant height was measured from ground level to the tip of the uppermost leaf. Plant shoots were cut at soil surface. Plant samples were placed in an oven at 60°C and dried until they attained a constant weight. Data collected were subjected to analysis of variance (ANOVA) to test for significant treatment effects. Statistical significance was evaluated at $P < 0.05$ and where the F-tests were significant, treatment means were separated using the least significant difference test (Gomez and Gomez, 1984).

*7.2.1 Methods of soil and manure analysis*

The soil used in this study has been classified as a Glenrosa soil form (Mulder, 1988). It is described as very shallow (0.45m) orthic A/lithocutanic B saprolite with brown A and red brown B horizon; clayey texture (15–25% and 35–45%) clay in A and B horizons respectively (le Roux, 2012). Soil analysis was conducted by the Fertiliser Advisory Services of the South African Sugar Research Institute (SASRI). Exchangeable acidity was determined by titration after extraction with 1 M potassium chloride. The pH was determined in $CaCl_2$. The elements P, K, Ca, Mg, Ca, Fe, Cu, Zn and Mn were determined by the method described by van der Merwe *et al*., (1984). P was determined colourimetrically after extraction with 0.02N sulphuric acid. Silicon was extracted overnight with 0.01 M calcium chloride determined as described by Miles *et al*., 2011. Manure analysis was conducted as for plant analysis as follows. For Zn, Cu, Fe, Mn and S a one gram sample was digested in 15ml nitric acid followed by 5 ml perchloric acid. After digestion, the resultant mixture was filtered and then made up to volume using water. The elements were then determined using atomic absorption (AA) spectrophotometer. For the analysis of N, P, K, Ca and Mg a 0.25g sample was digested in the 2 ml selenised sulphuric acid for one and a half hours in a Kjeldatherm block digester at a temperature of 370 °C. After digestion, the samples were diluted to volume with water and K, Ca and Mg were determined by AA. N and P and S were determined colourimetrically. The soil and manure analysis results are presented in (Appendix 3).

### 7.3 Results and Discussion

The soil analysis indicated that the soil was acidic although the clay content and total cations were quite high. C. *olitorius* has been reported to be tolerant and to grow quite well in acid soils (Facciola, 1990 cited in Musa *et al*., 2010). This could explain the good growth observed in the present study in which the pH ($CaCl_2$) was 4.58.

C. *olitorius* responded positively ($p<0.05$) to both basal fertiliser application and rate of nitrogen fertiliser (Table 8.1). Mineral fertiliser resulted in significantly ($p<0.05$) higher number of branches per plant (79% more than the control), marketable fresh weight (90% more than the control) and shoot dry weight, followed by cattle manure which resulted in 75% more branches than the control and 82% more fresh weight than the control (Table 7.1). Treatments receiving more than 200 kg/ha lime ammonium nitrate saw a depression in fresh yield and shoot dry weight, perhaps due to toxicity. The response to type of basal fertiliser was much more distinct than the response to different levels of nitrogen top dressing (Figures 7.1 to 7.5). Increases in *Corchorus* yield components in response to basal soil amendments, nitrogen application and the interaction of basal and nitrogen soil amendments have been reported in previous studies (Olaleye, 2008; Masarirambi *et al*., 2012; Makinde *et al*., 2011; Musa *et al*., 2010; Olaniyi and Ajibola, 2008; Nwangburuka *et al*., 2012)

There were significant ($p<0.05$) interactions between basal fertiliser and nitrogen top dressing on plant height, number of branches, marketable fresh yield and shoot dry mass (Figures 7.1, 7.2, 7.3 and 7.4 respectively). Generally, for the measured parameters (except for number of branches) where no basal fertiliser was applied, there were no significant ($p<0.05$) differences among the four nitrogen rates. For cattle manure and mineral fertiliser, the lowest ($p<0.05$) plant height, number of branches, marketable yield and shoot dry mass were obtained with no top dressing.

**Table 7.1** Main effects of basal fertiliser type and rate of nitrogen source on plant height and number of branches, marketable fresh weight and shoot dry weight of *Corchorus olitorius*

| | Plant height (cm) | Number of branches per plant | Marketable fresh weight (g/plant) | Shoot dry weight (g/plant) |
|---|---|---|---|---|
| Basal fertiliser type | | | | |
| No fertiliser (control) | 40.28 | 2.69 | 5.11 | 1.78 |
| Cattle manure | 88.18 | 10.86 | 28.84 | 15.89 |
| Mineral fertiliser (2:3:2 (22) | 88.50 | 13.08 | 49.99 | 24.23 |
| Significance | * | * | ** | ** |
| $LSD_{(0.05)}$ | 4.66 | 0.84 | 2.75 | 1.21 |
| Nitrogen level (kg/ha) | | | | |
| 0 | 69.96 | 6.37 | 16.55 | 9.91 |
| 100 | 74.51 | 9.85 | 27.76 | 15.48 |
| 200 | 72.59 | 9.37 | 34.00 | 15.97 |
| 300 | 72.21 | 9.93 | 33.61 | 14.50 |
| Significance | ns | * | ** | ** |
| $LSD_{(0.05)}$ | - | 0.96 | 3.18 | 1.40 |

ns, not significant, ** significant at $p<0.01$, * significant at $p<0.05$.

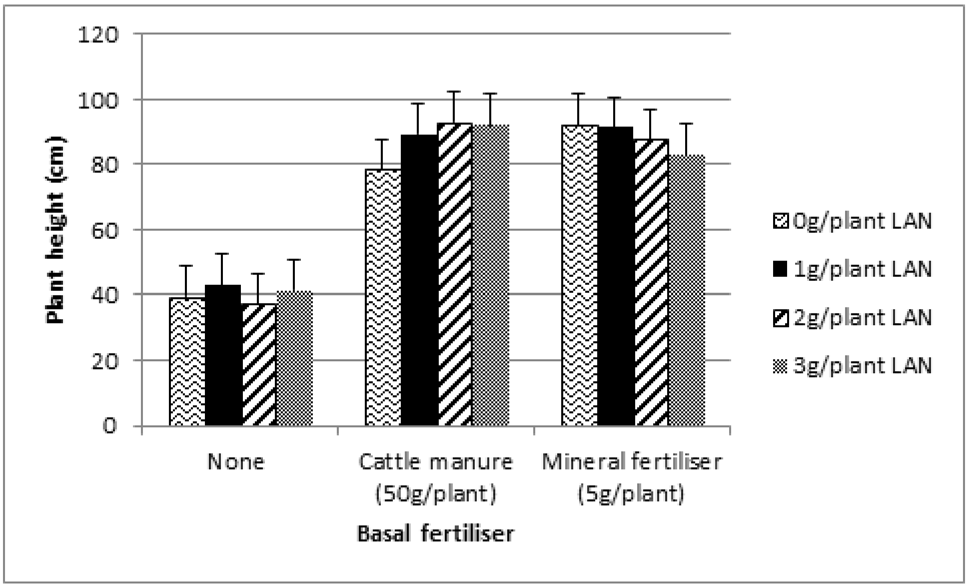


**Figure 7.1** Interaction between basal fertiliser and rate of lime ammonium nitrate (LAN) nitrogen fertiliser on *Corchorus olitorius* plant height.

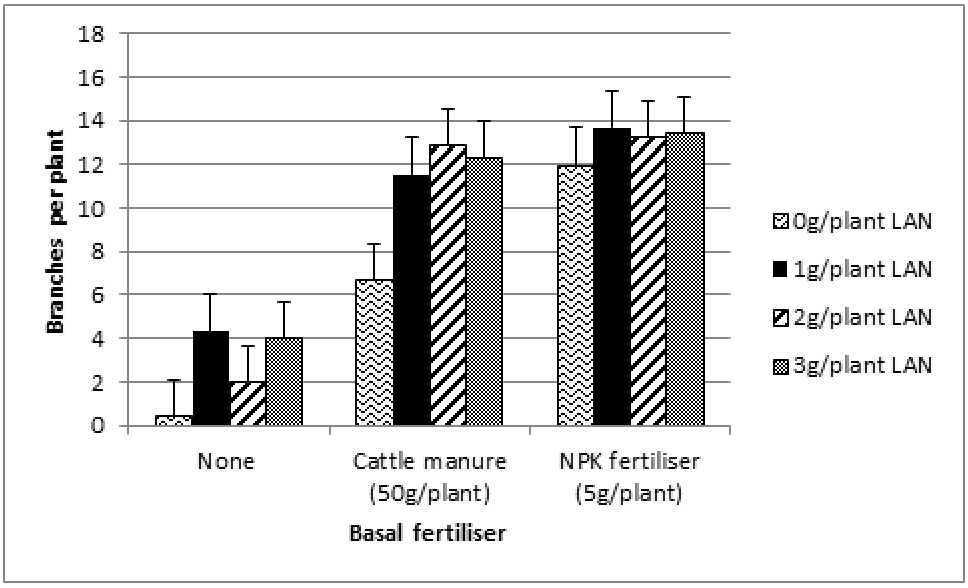


**Figure 7.2** Interaction between basal fertiliser and rate of lime ammonium nitrate (LAN) nitrogen fertiliser on *Corchorus olitorius* number of branches.

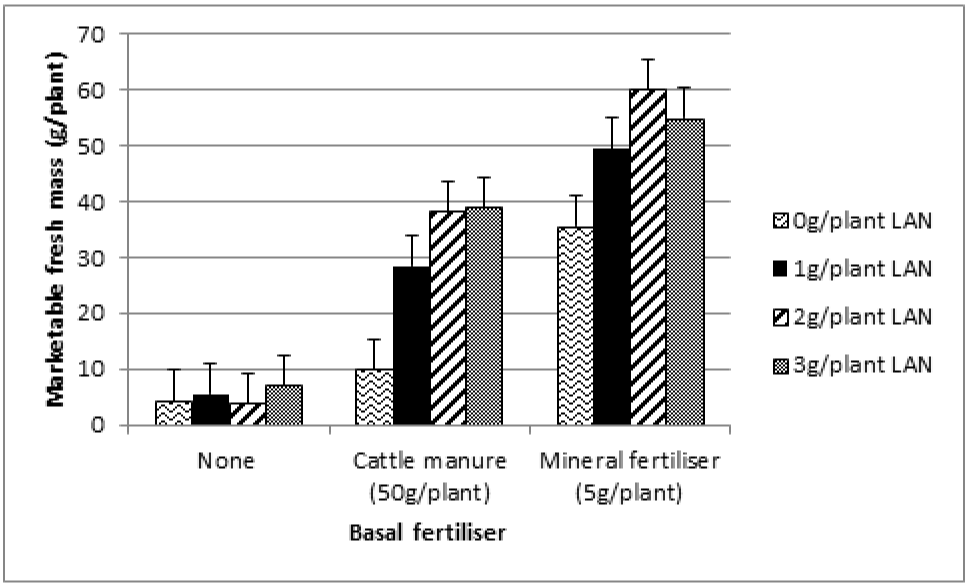


**Figure 7.3** Interaction between basal fertiliser and rate of lime ammonium nitrate (LAN) nitrogen fertiliser on *Corchorus olitorius* marketable fresh weight.

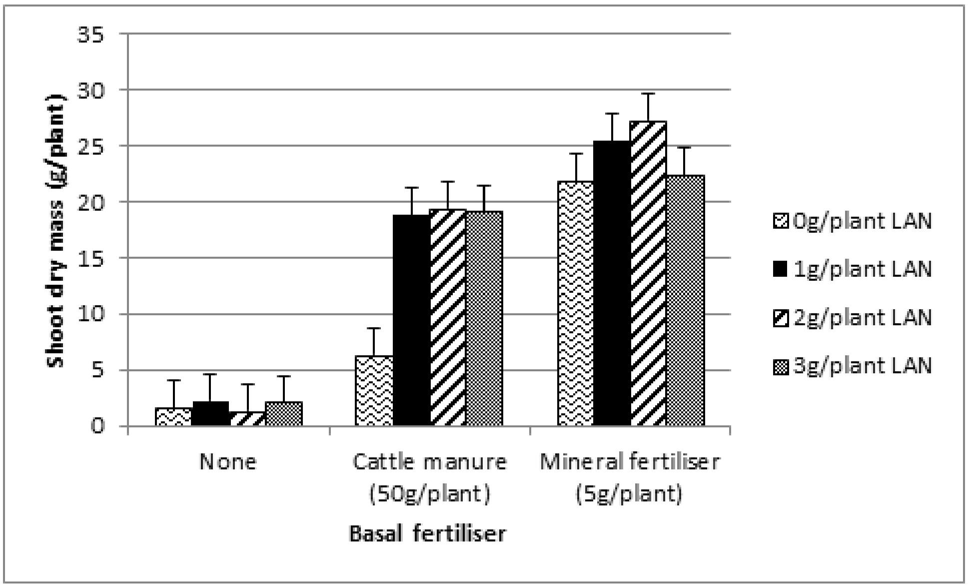


**Figure 7.4** Interaction between basal fertilizer and rate of lime ammonium nitrate (LAN) nitrogen fertiliser on *Corchorus olitorius* shoot dry mass.

**Figure 7.5** Effect of fertiliser on growth of *Corchorus olitorius*. From left to right: The plant on the extreme left was grown without fertiliser; the second plant was grown with cattle manure (CM) but no nitrogen (N) top dressing; third plant grown with CM and N top dressing. Plants 4 and 5 grown with mineral fertiliser (2:3:2(22)) and N.

The very low yields obtained without basal fertiliser application suggest that the productivity of unfertilised and uncultivated C*. olitorius* could be very low. This would suggest that yield per unit area from the wild *Corchorus* would be very low and gatherers would have to scour a wide area to gather sizeable portions of the vegetable. Under such circumstances, the chances of overharvesting on individual plants to the extent of impairing seed production are high, thereby threatening the species survival. Improved cultivation methods and the application of soil amendments would alleviate the problem by increasing the yield per unit area as suggested by this present study.

Where neither cattle manure nor mineral fertiliser was applied, N application alone did not result in statistical ($p<0.05$) differences in measured parameters. Bigger differences were found between basal fertiliser types than between nitrogen treatments. The soil used in this study was comparatively fertile with a reasonable CEC, moderate clay content, organic matter and reasonable quantities of other essential elements (FSSA, 2007). Although growing wild okra with cattle manure gave lower yields than with mineral fertiliser, the yields were still much higher than growing without any form of basal fertiliser. Subsistence farmers and organic oriented farmers would get better yields using cattle manure than growing without manure. For commercial production mineral fertiliser appears to be the best option. A study by Masarirambi *et al.*, (2012) in Swaziland showed that C. *olitorius* responded positively to incremental cattle manure application by increasing fresh leaf yield under dryland conditions. In the study, the highest yield was obtained by applying manure at 60 tonnes per hectare. Although the rate is quite high for large hectarages it could be practical for small vegetable gardens.

### 7.4 Conclusions and recommendations

It can be concluded from this study that C. *olitorius* growth parameters measured responded significantly to the application of both basal and top dressing soil amendments. Use of either manure or NPK was definitely advantageous to growing without fertiliser. The response of C. *olitorius* to LAN levels greater than 200 kg/ha and different rates of basal fertilises need to be investigated further, preferably under on-farm conditions. It is also recommended to evaluate the effects the different soil amendments to Corchorus nutritional and chemical composition.

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# CHAPTER 8

# Comparative evaluation of the germination capability of three morphologically different wild genotypes of *Corchorus olitorius* L. from northern KwaZulu-Natal, South Africa[19]

## 8.1 Introduction

Wild *Corchorus olitorius* is an indigenous species in Africa and it is utilised as a vegetable in many parts of the continent. It is known by many different names but the most common are ‘Jews mallow’ and wild/bush okra (Palada and Chang, 2003). The species has been domesticated in West Africa for several decades and it is most popular among the western population of Nigeria as weaning soup for children and good delicacy for adults. It is mostly known as a wild vegetable in southern Africa; still mainly collected from the wild and eaten or preserved by sun drying and eaten as off-season vegetable during food scarcity in northern parts of South Africa. The increased utilisation of wild vegetables like wild *C. olitorius* in South Africa has been suggested as one of the ways to alleviate nutritional deficiencies and household food insecurity especially among populations with marginal or no income (Lewu and Mavengahama, 2010; Bharucha and Pretty, 2010; Ohdav *et al.*, 2007; Jansen van Rensburg *et al.*, 2007; Modi *et al*., 2006). Any effort to domesticate, commercialise and increase the yield of wild vegetables will depend on increasing the germination capabilities of the vegetables as well as developing local seed supply systems so as to ensure reliable supplies of highly germinable seed; as is the case with other domesticated crops. Uncertain availability of seed, variation in the quality of seed, lack of variety selection for uniformity of desired agronomic traits are some of the identified constraints to the cultivation of wild vegetables (Smith and Ezyaguirre, 2007).

Other studies indicated that several indigenous vegetable species have sub-optimal germination capabilities; thus hindering cultivation efforts (Velempini *et al.*, 2003;

[19] Published as Mavengahama, S and Lewu, F.B. 2012. Comparative evaluation of the germination capability of three morphologically different wild okra (Corchorus olitorius) accessions from northern KwaZulu-Natal. African Journal of Biotechnology Vol. 11 (22): 6050-6054.

Emongor *et al*., 2004; Modi, 2007). If the recent calls to promote the consumption of wild vegetables due to their superior nutritional content are not matched with increased propagation and cultivation this could lead to an unsustainable increase in harvesting from the wild; an occurrence common with most species collected from the wild (Lewu *et al.,* 2007). Previous reports on the nutritional analysis of the wild population of the species indicated that *C. olitorius* contained more nutritional qualities in terms of crude protein, iron, calcium and magnesium than cabbage and spinach purchased from public vegetable store in South Africa (Ndlovu and Afolayan, 2008). There appear to be an upsurge in the collection of the species in the wild; and the influence of increased wild harvest is yet to be documented in South Africa. If the increase in consumption of this species is not matched with propagation and or cultivation, *C. olitorius* could end up with very low and unsustainable wild population or even go to extinction in South Africa. The cause of seed dormancy in *C. olitorius* has been suggested to be an impermeable seed coat (Emongor *et al*., 2004; Velempini *et al*., 2003). This might pose a challenge to propagation and cultivation initiatives. To achieve a successful commercial production of the species, there are several effective methods for breaking the type of dormancy (impermeable seed coat) in wild *C. olitorius*. Some researchers have reported very high germination percentages (between 80 and 90%) after subjecting seeds to sulphuric acid treatment (Velempini *et al.*, 2003; Emongor *et al.*, 2004) and variation in temperature (Nkomo and Kambizi, 2009). These studies may be more appropriate for large scale seed production systems where farmers can afford the cost of chemicals for scarification. However, few studies have documented the potential of solving hard seed coat dormancy in wild genotypes of *C. olitorius* especially among smallholder farmers in South Africa with limited financial resources and rudimentary knowledge of handling dangerous chemicals. With increasing population and rising level of poverty among this marginal income population, unsustainable harvesting of wild population of *C. olitorius* is inevitable; especially when the nutritional benefit of the species becomes increasingly known among the people.

Several methods, including heat treatment, scarification by acids and mechanical scarification can be used to open the seed coat. For smallholder rural farmers, scarification by acids is inappropriate due to cost, stringent handling and sale policy/requirements of the chemicals due to their hazardous nature. Mechanical scarification like puncturing of seed coat with a needle is possible for varieties with large seeds; but is still tedious and impracticable for small seeded varieties (like *C. olitorius*) and large seed-lots. Heat treatment was selected as an appropriate method for evaluation in this research. The choice of heat treatment became necessary due to the need to identify a suitable method that can easily be used at a rural household where laboratory heaters with controllable temperature baths and chemicals such as acids are not available. In this study heat treatment was separated into dry heat and hot water treatment. Therefore, the objective of this study was to identify the best and easiest heat treatment method that can be used by rural households of South Africa.

**8.2 Materials and methods**

The experimental design was a completely randomised design (CRD) with five replications. Fifty seeds were used per experimental unit and placed in Petri dishes lined with Whatman No 1 filter papers and moistened with sterile distilled water for the duration of the experiment. The Petri dishes were placed on the laboratory workbench at room temperature (25 - 28°C) for the duration of the study. Two factors were considered in the study which were; wild genotypes of *C. olitorius* (designated Co1, Co2 and Co3; Co being *Corchorus olitorius*) and heat treatment (T1 to T6) in a factorial combination, giving a total of 18 treatments as follows (Co1 xT1; Co1 x T2; Co1 x T3; Co1 x T4; Co1 x T5; Co1 x T6; Co2 x T1; Co2 x T2; Co2 x T3; Co2 x T4; Co2 x T5; Co2 x T6; Co3 x T1; Co3 x T2; Co3 x T3; Co3 x T4; Co3 x T5; Co3 x T6). Wild genotypes of *C. olitorius* were differentiated by visual assessment. Each genotype had distinct morphological differences with reference to leaf area, pod and seed sizes. Co1 had very small seeds, leaf area and pods. Co2 had medium pods, seed sizes and leaf area; while Co3 had large seeds, pod sizes and large leaf area.

The levels of heat treatments include: T1 – seeds placed on filter paper moistened with distilled water in a Petri dish (control); T2 – seeds tied inside nylon cloth and steeped in boiling water for ten seconds and dried, prior to germination. T3 - seeds placed on a hot aluminium lid and placed over a bath of boiling water for 5 seconds. T4 - seed placed on an aluminium lid over a bath of boiling water for 10 seconds. T5 – seed placed on an aluminium lid over a bath of boiling water for 15 seconds. For each of the aluminium treatments, the seeds did not have direct contact with the hot water but were allowed to absorb heat while the aluminium lid serves as heat transfer medium at the stated time periods respectively. T6 – seed tied in nylon cloth and placed in a water bath maintained at 80$^{o}$C for ten minutes. All treatments were placed on filter paper moistened with distilled water in a Petri dish for the duration of the experiment.

Measurements taken were germination percentage, number of days to final germination and the temperature for each heat treatment. The criterion for germination was a visible radicle emergence from the seed coat. Germination was recorded daily for 14 days and germinated seed was removed from the Petri dish.
Data collected were subjected to analysis of variance (ANOVA) using the Genstat Statistical package to test for significant treatment effects. Means were separated using Duncan's multiple range test (DMRT) (Steel *et al.*, 1997). Before analysis, count data were converted to percentages. The percentage data ranged from 0 to 82 and were, therefore, arc sine transformed (Gomez and Gomez, 1984). Prior to transformation, zeros were replaced by (1/4*n*) where *n* is the number of units upon which the percentage data was based. A denominator of 50 was used for computing the percentage in the present study (Gomez and Gomez, 1984).

### 8.3 Results

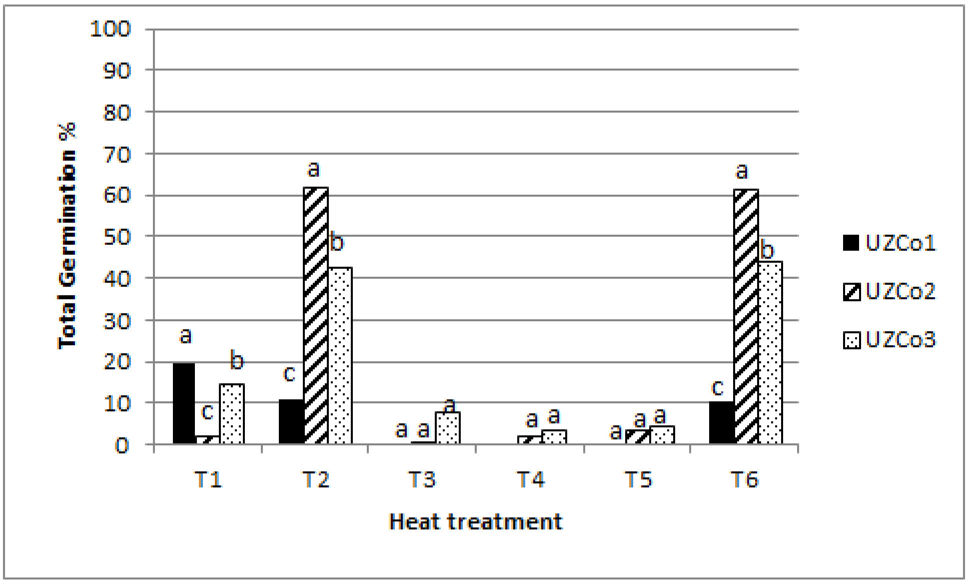
There was a significant difference ($p<0.01$) in the germination percentage of the three genotypes with genotype Co2 having the highest response to germination whereas Co1 recorded the lowest germination percent. Heat treatment resulted in statistically significant ($p<0.01$) differences in germination (Table 8.1). The three dry heat treatments (T3, T4 & T5) resulted in lowest germination; dropping lower than the control. Steeping seeds for 10 minutes in water maintained at 80$^{o}$C (T6) resulted in numerically highest germination, although was not statistically different from T2.

**Table 8.1** Main effect of heat treatment on germination percentage of *Corchorus olitorius* from northern KwaZulu-Natal

| Heat treatment | Germination % (arc-sine transformed | Germination % (actual) |
|---|---|---|
| T1 | 12.04b | 6.13b |
| T2 | 38.32a | 45.53a |
| T3 | 2.87c | 0.80c |
| T4 | 1.95c | 0.40c |
| T5 | 2.69 | 0.67c |
| T6 | 38.71a | 42.93a |

**T1** – seed placed on filter paper moistened with distilled water in a Petri dish (control); **T2** – seed tied in nylon cloth and steeped in boiling water for ten seconds and dried; **T3** seed placed on a hot aluminium lid placed over a bath of boiling water for 5 seconds. **T4** seed placed on the lid over a bath of boiling water for 10 seconds. **T5** seed placed on aluminium lid over a bath of boiling water for 15 seconds. **T6** seed tied in nylon cloth and placed in a water bath at 80°C for ten minutes. Means within the same column with different letters are significantly different at 5 % level by DMRT.

This study showed significant interactions between heat treatments and the genotypes (Figure 8.1). The two hot water treatments T2 and T6 resulted in similar germination trends across all genotypes. Genotype Co2 recorded the highest level of germination followed by Co3 with the lowest response to germination being Co1. The highest germination percentage for Co1 (20%) was achieved with the control. The three dry heat treatments resulted in significantly low percentage (<10%) germination for the three genotypes.




**T1** – seed placed on filter paper moistened with distilled water in a Petri dish (control); **T2** – seed tied in nylon cloth and steeped in boiling water for ten seconds and dried; **T3** seed placed on a hot aluminium lid placed over a bath of boiling water for 5 seconds. **T4** seed placed on the lid over a bath of boiling water for 10 seconds. **T5** seed placed on aluminium lid over a bath of boiling water for 15 seconds. **T6** seed tied in nylon cloth and placed in a water bath at 80°C for ten minutes. Co1- *C. olitorius* accession 1; Co2- *C. olitorius* accession 2; Co3- *C. olitorius* accession 3. Means at each heat treatment were separated by DMRT at 5% level of significance

**Figure 8.1** Interaction effects of heat treatment methods and genotypes on germination of *Corchorus olitorius* seed.

## 8.4 Discussion

The three genotypes evaluated in this study were collected from the same natural population. The mother plants possess distinct morphological difference with reference to leaf area, fruit and seed sizes. Our findings suggest that wild *C. olitorius* seeds with different sizes may require diverse durations of exposure to hard seed coat dormancy-breaking treatments. Previous reports appeared to miss this important morphological seed difference when giving production guidelines and advice (Velempini *et al.*, 2003; Palada and Chang, 2003; Emongor *et al*., 2004). The present result is supported by early observation that multiplication and propagation of *C. olitorius* is constrained by high level of morphotypes (Adebooye and Opabode, 2004). Similar result was also reported on agronomic requirements of *Cleome gynandra* “cat’s whiskers” (Chigumira, 1995). There is need for morpho-genetic characterisation of wild populations of *C. olitorius* so as to develop distinct varieties.

This will help to reduce the challenge of varietal differences and the mixing of genotypes and morphotypes during cultivation and propagation programmes.

Although treatments of wild *C. olitorius* seeds with acids such as nitric and sulphuric acids resulted in very high germination percentages, these acids are very dangerous, require training in handling and are not recommended in the smallholder farming conditions. Therefore, there is the need to develop other appropriate, simple and effective ways of breaking the seed coat induced dormancy in wild *C. olitorius*. Heat treatment becomes an appropriate and handy method to circumvent hard seed coat induced dormancy in traditional households with limited skill in handling more advanced and dangerous scarification technologies. Steeping seeds in hot boiling water for 10 seconds achieved about 60% germination for the medium sized (Co2) seeds. Other studies on wild *C. olitorius* reported higher germination percentages (Velempini *et al*., 2003; Emongor *et al*. 2004) without reference to possible germination differences due to seed sizes. The current study emphasised this difference and further reinforce the importance of morpho- genetic variation in seed germination studies. Dry heat probably killed the seeds of genotype Co1 as there was almost zero percent germination for all the three dry heat treatments. For genotypes Co2 and Co3, dry heat may possibly not have been effective in breaking the dormancy as limited germination was observed. Genotype Co1 achieved the highest germination (20%) without heat treatment, yet when hot water treatments (T2 and T6), were applied, the germination percentage dropped by 50% (10%) and almost to zero percent for all the three dry heat treatments. Following our results of this study, it is highly suggestive that heat treatment killed the very small seeds of genotype Co1.

That some seeds of the three genotypes still germinated without heat treatment suggests that some portion of wild *C. olitorius* seeds were able to overcome hard seed coat dormancy without any treatment. The few seeds that are able to overcome imposed seed dormancy in wild populations of the species could be responsible for the natural regeneration of wild *C. olitorius* in its natural habitat. This observation also suggests that the natural regeneration capability of wild *C. olitorius* in its natural habitat is very low and may not support unsustainable harvest. In circumstances where the harvesting of the species from the wild increases, there will be need for farmers to collect seed and propagate the vegetables in home gardens or fields to prevent genetic erosion. The observation that the hot water treatments (T2 and T6) caused about 60% germination for the medium sized seeds and about 40% germination for the larger sized seeds indicates that more exposure period to hot water could increase the germination percentage of both the medium and large sized seeds. Without further empirical evidence, it would be difficult to draw any meaningful explanations for the extremely low germination of the medium and larger sized seed with the three dry heat treatments. It is highly probable that the dry heat treatments may not have been adequate to break the dormancy of the medium to large seeds but were enough to kill the seeds of the smaller sized seeds. Further investigation of this postulation is therefore necessary.

## 8.5 Conclusion

Wild *C. olitorius* varieties with different seed sizes require a different exposure time to heat treatment methods to break impermeable seed coat dormancy. Steeping medium to large sized seed of wild *C. olitorius* in 80$^{o}$C hot water for 10 minutes and in boiling water for 10 seconds resulted in the highest germination percent. However, there is a need for the characterisation of different wild *C. olitorius* varieties for further differentiation into their morphological classes.

## 8.6 References

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# CHAPTER 9

## Yield response of bolted spider plant (*Cleome gynandra*) to deflowering and nitrogen top dressing[20]

### 9.1 Introduction

Spider plant or Cat's whiskers (*Cleome gynandra*) is a wild species which is commonly consumed as a vegetable in various parts of Africa. Besides its culinary value, the plant is also used as a medicinal herb for the treatment of various ailments (Opole *et al*., 1995 cited in Mauyo *et al*., 2008). It is an upright annual herb multi-branched and grows to about 60 cm in height (Mishra *et al*., 2011; NDA, 2012). Among the wild vegetables C. *gynandra* has been reported to flower prematurely. This phenomenon, known as bolting is common in many vegetable crops including Brassicas and has been described as a physiological disorder (Masarirambi *et al*., 2011). It can be as a response to temperature extremes and photoperiod and affects many other vegetables such as lettuce (*Lactuca sativa*), spinach (Royal Horticultural Society, 2012) and mustard rape (*Brassica juncea*) (Masarirambi *et al*., 2011). In general, bolting leads to production losses as crops flower before they have produced an economic yield (see Figure 9.1), that is, when they are still in the nursery or soon after emergence, if directly seeded or soon after transplanting. The grower would have invested in a seedbed only for the plants to flower before they have given any economic yield so as to offset the grower's production costs. However in C. *gynandra* the problem of bolting seems to be induced by other factors besides temperature and day length, most likely genetic factors. This is due to the observation that even when established throughout the year it still bolted.

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a

b

c

**Figure 9.1** (a) and (b) Prematurely flowered or ‘bolted’ *Amaranthus cruentus* and (c) prematurely flowered *Cleome gynandra* plants. It is evident from the photographs that the plants flowered before they had grown big enough to give an appreciable quantity of leaf yield.

Researchers differ in their characterisation of C. *gynandra* in terms of genetic uniformity. Chigumira (1995) reported much variability in a particular variety yet Omondi (1990) reported uniformity of most characteristics of Cleome although he suggested that there is likely to be considerable outcrossing due to observed diverse phenotypes (Chweya and Mnzava, 1997). C. *gynandra* seed germination has also been reported to be erratic (Chweya and Mnzava, 1997; Chigumira, 1995). As a semi domesticated crop there are wide variations in the characteristics of C. *gynandra* ranging from whether it is self-pollinated (Omondi, 1990) or cross pollinated due to observed protandry (Chweya and Mnzava, 1997) to whether seeds require a rest period or they germinate immediately after harvesting (Chweya and Mnzava, 1997). Breeding studies have shown a high heritability estimate for flowering, suggesting it is possible to select for late flowering trait in C. *gynandra* (Chweya and Mnzava, 1997).

This present study was prompted by the unexpected flowering of C. *gynandra* seedlings when they were about to be transplanted. C. *gynandra* had been planted together with *Corchorus olitorius* and *Amaranthus* spp. The other two vegetables did not bolt and were successfully transplanted and they went on to grow and only flowered much later in the season. We then postulated that the removal of flowers and the application of nitrogen top dressing would stimulate vegetative growth and lead to utilisable and economic leaf yield, thus salvaging the bolted crop. The premature flowering of C. *gynandra* would hamper current efforts to promote it among rural farmers in South Africa. Presently the University of Zululand and the Agricultural Research Council are in the process of promoting wild vegetables to rural farmers. With its unpredictability C. *gynandra* would present a lot of propagation challenges to these farmers. It would limit the yield obtained and also shorten the production season leaving farmers exposed to shortages.

### 9.2 Materials and methods

The experiment was conducted in an open sided polycarbonate roofed shelter at the University of Zululand main campus at KwaDlangezwa (lat. 28$^o$51'S; long. 31$^o$51'E). C. *gynandra* seeds were sown in commercial medium Hygromix® in 200 cell polystyrene trays. Sowing was done on 17$^{th}$ July 2012. Several seeds were sown per cell. Seed was obtained from the Agricultural Research Council Vegetable and Ornamental Plant Institute (ARC-VOPI).

Emergence commenced 23 July 2012, five days after sowing (DAS). The germination was very uneven. Where more than one seed germinated per cell, thinning was done to leave one seedling per cell. Lime ammonium nitrate (LAN) and Multifeed® fertiliser were applied on 10 August 2012 (24 DAS) to supply nitrogen and micronutrients respectively. Seedling growth was generally very slow. On 21 August 2012 (34 DAS) seedlings suddenly elongated overnight and on 22 August they flowered in the trays. This flowering was unexpected and as result the seedlings could not be used in the intended experiment where they were going to be compared to *Amaranthus cruentus* and *Corchorus olitorius*.

Transplanting was done on 25 August 2012 (38 DAS) into 2.5 litre polythene bags filled with soil obtained from the University of Zululand farm. The soil has been classified as a Glenrosa soil form (Mulder, 1988). Glenrosa soil is described as very shallow (0.45m) orthic A/lithocutavic B saprolite with brown A and red brown B horizon; clayey texture (15 -25% and 35 – 45% clay in A and B horizons respectively (le Roux, 2012). A basal fertiliser application of 2:3:2 (22) + 0.5% Zn was applied at a rate of 5g per plant, corresponding to 500 kg/ha for a recommended plant population of 100 000 plants per hectare when fertiliser is applied per planting station. All transplanted seedlings had flowered and seedlings of the same size were selected for this study. There were two factors in this experiment; flowering and nitrogen topdressing. Flowering had two levels; not deflowered and deflowered. Nitrogen source was lime ammonium nitrate (LAN) (28% nitrogen) and had three levels; 0kg/ha, 150 kg/ha and 300 kg/ha. LAN was applied as two equal splits on 03 September 2012 ten days after transplanting (DAT) and 23 September 2012 (30 DAT). Harvesting was done thrice on 23 September 2012 and 7 and 21 October. For the deflowered treatments, deflowering was done continuously until the final harvest.

### 9.2.1 Methods of soil analysis

Soil physico-chemical analyses were conducted by the Fertiliser Advisory Services of the South African Sugar Research Institute using methods in the Handbook of Standard Soil testing Methods for Advisory Purposes as recommended by the Independent Soil Analysis Working Committee. Soil pH was determined in CaCl2. Exchangeable acidity was determined by titration after extraction with 1 M potassium chloride. The macronutrients K, Ca, Mg and Ca and micronutrients Fe, Zn and Mn were determined the Inductively Coupled Plasma spectrophotometer after extraction with the Ambic–2 extraction method using EDTA-di-ammonium solution. Truog extractable P was determined colourimetrically using modified Murphy and Riley molybdenum blue method. The soil analysis results are presented in Appendix 3.

## 9.3 Results and Discussion

Removal of flowers and nitrogen application resulted in significant ($P<0.05$) differences in the fresh and dry weight of cleome leaves (Table 9.1).

**Table 9.1** Main effect of de-flowering and lime ammonium nitrate (LAN) nitrogen top dressing on fresh and dry leaf weight of *Cleome gynandra*

| Treatment | Fresh leaf weight (grams/plant) | Dry leaf weight (grams/plant) |
|---|---|---|
| **Flowering status** | | |
| Not deflowered | 13.75 | 3.26 |
| Deflowered | 20.02 | 4.61 |
| Significance | ** | ** |
| $LSD_{(0.05)}$ | 2.43 | 0.50 |
| **Nitrogen rate** | | |
| 0 kg/ha LAN | 11.88 | 3.07 |
| 150 kg/ha LAN | 17.61 | 4.01 |
| 300 kg/ha LAN | 21.17 | 4.73 |
| Significance | ** | ** |
| $LSD_{(0.05)}$ | 2.98 | 0.62 |

** Significant at $p<0.01$

Removal of flowers resulted in a 46% increase fresh weight. The observed positive response of leaf yield to removal of flowers offers a possible way to deal with the problem of bolting. However this would only be useful where production is on a small scale as the process is quite tedious. The solution would be best for small scale producers. Although there is a paucity of information on the flowering of C. *gynandra*, frequent picking has been suggested to delay flowering and prolong the harvesting period (CTDT, 2008). It would appear that deflowering stimulates vegetative growth. The removal of the apical shoots in plants is known to stimulate the growth of lateral shoots which develop into branches as confirmed by Masinde and Agong (2011) who removed flowers so as encourage vegetative growth of C. *gynandra.* Removal of the tips of primary branches led to the formation of secondary branches on which grew more foliage. Thus deflowered plants had more strata of branches than plants which were not deflowered. Frequent picking and deflowering encourage growth of lateral resulting in many active shoot apices on a plant. This extends the vegetative period. In *Bidens pilosa*, another wild species utilised as a vegetable, deflowering resulted in taller plants with a higher shoot weight (Zobolo and van Staden, 1999). The authors concluded that flowering was responsible for reduction of post-flowering leaf and stem growth and that deflowering reduced senescence, thus maintaining vegetative growth.

In the present study, application of nitrogen increased leaf dry matter as well as overall plant dry matter. In studies by Mauyo *et al*., (2008) and Masinde and Agong (2011) incremental application of nitrogen from calcium ammonium nitrate source resulted in increase in plant height, number of shoots and utilisable leaf and shoot yield of C. *gynandra*. In the study by Masinde and Agong application of 3.12 grams N per plant resulted in three times higher leaf dry weight compared with no nitrogen applied. The other studies reported higher yields of C. gynandra compared to those obtained in this study. This likely due to the fact that in the other studies they included growing points (shoots) as part of the yield, yet in this present study we only included leaf weight and not the weight of shoots.

### 9.4 Conclusions

It can be concluded from this study that C. *gynandra* is prone to premature flowering. This premature flowering leads to drastic reduction in utilisable leaf and shoot yield. The continuous removal of the flowers leads to increased utilisable leaf yield. The application of incremental amounts of nitrogen top dressing resulted in increased leaf yield in C. *gynandra.*

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# CHAPTER 10

## Challenges in evaluating the nutritional composition of wild vegetables[21]

### 10.1 Introduction

The nutritional composition of wild vegetables (WV) has been studied and reported by several researchers (e.g. van der Walt *et al*., 2009; Flyman and Afolayan, 2006; Modi *et al*., 2006; Odhav *et al*., 2007; Maunder and Meaker, 2007; Nesamvuni *et al*., 2001; Steyn *et al*., 2001; Gupta *et al*., 2006). There is a general agreement in the literature that these vegetables are good sources of micronutrients and sometimes have superior nutritional composition when compared with common vegetables such as Swiss chard and cabbage. The studies also generally indicate that these vegetables are particularly rich in the micronutrients pro-vitamin A and iron. Some of this information has been obtained by comparing the WV with cultivated crops that have been produced under controlled conditions of fertilizer application, irrigation and other growing conditions making such comparisons biased in favour of the cultivated crops. Yet even with this bias, these studies have indicated higher levels of nutrients in the WV. This would suggest that WV have an inherent ability to concentrate micronutrients in their tissue, as also reported by Chapin (1980). However, a report by Oelofse and van Averbeke (2012) on a long term study of indigenous leafy vegetables suggested the levels of micronutrients may be lower than expected.

This review focuses on micronutrients in wild vegetables for several reasons. Micronutrient under-nutrition is a serious problem worldwide (FAO 2009; Nube and Voortman, 2006; Welch and Graham, 2004). As an example, a considerable proportion of the population in both urban and rural areas in South Africa is food insecure (Altman *et al*., 2009) and suffers from malnutrition (especially micronutrient malnutrition) (Faber and Wenhold, 2007; Faber *et al*., 2007). The estimates of the affected people seem to vary between different studies and this has been attributed

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[21] Mavengahama, S., Mclachlan, M. and de Clercq, W. In prep. Challenges that can affect the accuracy and reliability of evaluating the micronutrient composition of wild vegetables under smallholder conditions in South Africa.

to absence of a widely agreed standard of what constitutes food insecurity (Altman *et al*., 2009) and as a result the statistics are highly variable. Estimates indicate that about 265 million people in sub-Saharan Africa are undernourished (FAO, 2009). The same report also notes that the number of undernourished people has been increasing from the 1990s. White and Broadly (2005) reported that the diets of about two-thirds of the global population are deficient in one or more essential elements. Staple diets are usually deficient in micronutrients (Welch and Graham, 2004) and therefore WV have the opportunity to complement staple foods in this regard since studies seem to suggest that WV are rich in these micronutrients and are widely available in rural areas during the summer season. The supplementation of lacking micronutrients in the diet using WV could be the most economical measure which can be complemented by other measures such as bio-fortification and agronomic fortification (White and Broadly, 2009) and food supplementation.

### 10. 2 Problem statement

Compared with the level of research and scholarship in other food plants, WV research in South Africa is still limited and sporadic (Lewu and Mavengahama, 2010; Oelofse and van Averbeke, 2012) and as such important nutritional data on many aspects of these plants are unavailable. Methods for important analyses such as bio-availability are not universally available and are not standardised. The wide variability in methods coupled with the wide variability in the composition of the vegetables themselves from place to place pose complex challenges in the interpretation of analysis results. For most studies in the literature, nutritional information of WV is usually based on the conventional analysis of raw (fresh and uncooked) plant samples. However, research has shown that the total nutrients obtained in laboratory food analyses are not always an accurate measure of the nutrients that are available for absorption and assimilation in the body after consumption. Accurate nutritional data for various food groups are essential in the compilation of national food composition tables (Wolmarans and Danster, 2008). Sampling of cooked ready-to-eat vegetables would give a better estimate after accounting for any changes in nutritional composition brought about by post-harvest handling and the cooking processes. Challenges that are encountered when trying to determine the nutritional composition of WV are discussed in this analysis. Some of these challenges could have the effect of either understating or overstating both the nutritional composition of WV and the amounts of nutrients that humans can actually derive from these plant species.

The goal of this review is to highlight some of the challenges that cause wide variability in the reported nutritional composition of WV. The paper has attempted to answer the following research questions:

1. What factors influence the reported nutritional composition of wild vegetables?
2. How do variations in the methods of analysis of WV impact on our understanding of the nutritional value of these vegetables?
3. What do we know about the bioavailability of different micronutrients in WV and what factors influence their bio-availability?

### 10.3 Procedures used for literature search

The literature search was done using the Google scholar search engine. A snowball searching technique was employed (Mouton, 2012). In this method, search terms were executed in Google scholar and the publications that came up were content analysed. The relevant and highly cited (as indicated by the number of citations) publications were then searched by title and author, for instance, in the ISI Web of Knowledge. The authors who were cited by the selected authors were searched for and new authors who came up were continually searched in the Web of Knowledge and Google scholar.. Example of searches that were executed include: “nutritional composition of wild vegetables” or “nutritional composition of indigenous vegetables” or “composition of wild vegetables”. Some terms that are variously used to refer to WV were also included in the execution of searches. These terms include “African leafy vegetables”, “indigenous vegetables” and “green leafy vegetables”. The terms “bioavailability of wild vegetables” or “bioavailability of indigenous vegetables” were also executed. Relevant papers that were published in peer reviewed journals mostly between 2000 and 2012 were included in this present review.

## 10.4 The challenges

### *10.4.1 Influence of the environmental and plant part on nutrient content*

#### *10.4.1.1 Environmental influences*

The levels of antioxidants and micronutrients are a function of geographical and agro-climatic conditions (Aldrich *et al*., 2011). A study of one of the most commonly occurring wild vegetable in South Africa, *Amaranthus spp*., by Modi (2007) confirmed that environmental factors such as ambient temperature during crop growth influence the nutritional composition. In the study, leaf protein and amino acid content were highest when Amaranthus was grown in a cooler environment. Leaf calcium and iron content increased with temperature increase. Phosphorus was non-responsive to temperature in the study. Modi (2007) concluded that Amaranthus is most nutritious when grown under warm temperatures. Tarwadi and Agte (2005) suggested that dietary recommendations must be specific to particular geographical areas based on the types of fruits and vegetables occurring in that area and instead of general statements like 'African leafy vegetables are rich in micronutrients', it is necessary to specify which nutrients are abundant in which vegetable and from which place the vegetables were sampled. The same point was made by Wolmarans and Danster (2008) who recommended country-specific databases of food composition.

#### *10.4.1.2 Variability in nutrients due to different plant parts, plant age and varieties*

A comparison of studies has revealed very wide variability in reported nutritional content in WV (e.g. Odhav *et al*., 2007; Wallace *et al*., 1998; Flyman and Afolayan, 2008). However, this is not a trend only observed in WV but also in conventionally grown crops like Brassicas. For example a review of studies on mineral dynamics in Brassica species revealed that they are quite complex with almost every study showing variability in the accumulation of nutrients in the leaf with age and variety (Miller-Cebert *et al*., 2009; Khader *et al*., 2003; Bloem *et al*., 2010; Korus *et al*., 2009; Singh *et al*., 2009; Tarwadi and Agte, 2005; Wolmarans and Danster, 2008). Akwaowo *et al.* (2000) also found interactions between the age of different plants and nutritional and anti-nutrients composition. Similar effects of plant age were also reported in studies by Modi (2007) working with Amaranthus and Flyman and Afolayan (2008) working with *Mormodica balsamina* and *Vigna unguiculata*.

In the smallholder sector, leaves, shoots, stems and flowers of WV are usually mixed and cooked together. However in supermarkets and our own observations at University of Zululand farm for example, leaves are the predominantly packaged part of the vegetables. The tender shoots, stems and flowers are mostly discarded. A comprehensive study of the plant parts of fluted pumpkin by Akwaowo *et al*., (2000) revealed that different plant parts have significantly different nutritional composition. Utilisation of shoots and tender stems would help increase the bulk available for harvesting but the nutritional merits of these plant parts need to be studied so as to be able to give informed advice to consumers.

Comprehensive characterization of WV is needed in respect of nutritional, chemical and toxicological properties (Wallace *et al*., 1998; Flyman and Afolayan, 2006; Orech *et al*., 2005). Further analysis beyond the mostly analysed crude protein is required as research has suggested that crude protein does not indicate if essential amino acids are present. For example, Wallace *et al*. (1998) analysed leaf proteins and found that they were deficient in more than one amino acid – and therefore would be no better than conventional plant sources of protein. Most chemical tests on WV include those chemicals that are beneficial to humans such as carbohydrates, crude protein, antioxidants, vitamins, and minerals. Besides anti-nutritional factors such as phytate, tannins and oxalate, some WV have been shown to contain potentially toxic chemicals. A study by Orech *et al*., (2005) characterized *Amaranthus hybridus, Asystasia mysorensis, Coccinia grandis, Crotalaria ochroleuca* among others for alkaloids, saponins, cardenolides, flavonoids and polyphenols. All the vegetables in the study were found to contain flavonoids and polyphenols whilst the other chemicals varied from species to species. They concluded that the toxic chemicals in these species could cause chronic and acute toxicities if they were consumed in huge amounts for prolonged periods of time. Whilst polyphenols have noted toxicity and anti-nutritional properties, some researchers indicated that they have beneficial health effects on cancer and cardiovascular disease (Manach *et al*., 2004). The presence of toxic chemicals has implications for agronomic studies involving the application of fertilisers and soil amendments. There are possibilities that nitrogen and other elements can promote the production of undesirable active chemicals such as toxic substances. Studies in chilli (*Capsicum annuum*) have indicated that increasing levels of N application led to an increase in the levels of the active compound capsaicin, the compound that causes the pungency or hotness in chilli peppers. (Monforte-Gonzalez *et al*., 2010; Johnson and Decoteau, 1996). It is important for researchers in WV plant nutrition to study the possible correlation between increases in yield and nutritional composition of WV supplied with nitrogen or improved soil fertility and in toxic chemicals and anti-nutritional factors before giving final recommendations..

*10.4.2 Methodological and technical challenges*

For the analysis of organic components such as carotenoids, most laboratories rely on existing protocols. This is not usually a problem for conventional crops that have been researched for centuries as these protocols are readily available. Harvestplus described protocols for field crops such as barley (*Hordeum vulgare*), bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), maize (*Zea mays*), pearl millet (*Pennisetum typhoides*), rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), potato (*Solanum tuberosum*), sweet potato (*Ipomea batatas*), cassava (*Manihot esculenta*), yam (*Diascorea* spp) and wheat (*Triticum aestivum*) (Stangoulis and Sison, 2008).

To our knowledge, there are currently no standardised protocols for the analysis of bioavailability of micronutrients for most of the wild vegetables. It would appear that each research team that conducts bio-availability analysis develops its own protocols which may be different from other laboratories. During our current research work with WV we could not locate a research laboratory that routinely conducts bio-availability analysis for WV in South Africa. For the analysis of organic components such as carotenoids, the need to optimise protocols for each vegetable and for each laboratory makes the process expensive. Also the equipment and methods of analysis themselves are so varied and may not be comparable, as a result it is difficult to generalise on the composition of these vegetables as there are no standards developed. This lack of standardisation makes the methods prone to error. For example Du *et al*., (2000) compared three methods that are widely used to estimate the bioavailability of iron and they concluded that while these methods worked in Western (European and American) diets they were not applicable in China. The reasons they cited were that the dietary patterns and the methods of food preparation differed significantly enough to influence the composition of the food after preparation (cooking). They concluded that each of the three methods of estimating iron bioavailability had limitations. Wolmarans and Danster (2008) reviewed the methods for food nutrient analysis and concluded the use of inappropriate methodologies can cause serious errors which will have repercussions as decision making will be based on erroneous information. Some of the challenges encountered in the development of sampling and analysis methods have been discussed by Lashbrooke *et al.* (2010). It can be concluded from the foregoing that most of the available methods for food analysis in general can still be improved upon.

`*10.4.3 Influence of anti-nutritional factors and dietary diversity and composition on nutrient availability*

An important concept in nutritional studies is bioavailability which has been defined as. *"the proportion of the total in a food, meal or diet that is utilized for normal metabolic functions"* (Gupta *et al*., 2006). It is influenced by the presence in a meal of substances that either inhibit or promote the uptake of nutrients by the gut (Lonnerdal, 2002, 2003; Gupta *et al*., 2006). These substances include phytate, oxalate and polyphenols. These chemicals, variously called anti-nutrients or anti-nutritional factors, occur not only in WV but also in cultivated vegetables and fruits (oxalate), cereal and legume seeds (phytate) and beverages such as tea and coffee (polyphenols) (White and Broadly, 2009; Welch and Graham, 2009). It is estimated that only about 25% and 5% of the zinc in cereals and legumes respectively is bioavailable. The bioavailability of the nutrients in mainstream foods in general is complex and not yet well understood (Welch and Graham, 2009). As for WV, much more work on bioavailability and food value analysis is needed. From the limited research that has been done on this aspect thus far, WV are reported to have some anti-nutritional factors which bind zinc, calcium and iron. If mixed with other foods in the diet WV may result in non-availability in otherwise normally available nutrients from other foods that do not have anti-nutrients. They could render the micronutrients from the staples unavailable.

Most chemical analyses of vegetables are usually done for individual vegetables yet in reality people mix two or more vegetables when preparing meals. The issue was also raised by Du *et al*., (2000) and Welch and Graham (2009) in their reviews of methods of estimating iron bioavailability. They concluded that these methods had limitations for universal use in that they considered factors that promoted iron bioavailability separately yet in reality many kinds of foods that contain factors that either inhibit or promote the bioavailability of nutrients are eaten simultaneously in one meal. What this means is that the interaction between nutrient bioavailability inhibitors and promoters needs to be studied and understood more if a clearer picture of the dynamics of nutrient bioavailability is to emerge. The foregoing suggests, therefore, that the current methods of micronutrient bioavailability analysis in vegetables have limitations in that most of the studies have considered WV on their own yet in reality they are eaten in mixture with other foods. It would be worthwhile to conduct more studies in which vegetables that have been served for a meal are sampled. Such a study was conducted by Agte *et al*., (2000) who compared the micronutrient composition of meals containing green leafy vegetables. The levels of beta-carotene and folic acid were significantly highest in a meal prepared with cereal and green leafy vegetables and lowest in a meal prepared with cereal and sprouted legume (Agte *et al*., 2000). It is also known that there are certain substances that enhance the uptake up iron, e.g. ascorbic acid (Uusiku *et al*., 2010) and beta-carotene while cysteine rich polypeptides derived from both animal and plant sources are reported to promote copper, zinc and iron absorption (White and Broadly, 2009). Du *et al*. (2000) also found that food from animal sources and ascorbic acid enhanced non-heme iron availability but tea, rice and beans inhibited non-heme iron availability.

*10.4.4 Accounting for post-harvest handling: storage, cooking, preservation*

Nutrients such as carotenoids begin to disintegrate soon after harvesting and this has been reported to be irrespective of storage but due to enzymatic as well as non-enzymatic oxidation (Namita and Negi, 2010). Post-harvest handling of WV is very variable (Masarirambi *et al*., 2010) especially in the smallholder (SH) sector where refrigerating facilities are not widely available. There is need for post-harvest studies to characterise those WV being sold on the market in both rural and urban areas to determine the effect of time after harvesting and storage on chemical and physical quality. Some products of disintegration may be beneficial e.g. antioxidants formed from the breakdown of carotenoids after harvesting. The relationship between age and nutritional composition needs to be determined for various wild vegetable species so that recommendations can be given for them to be harvested when they have optimal nutrition. Unfavourable temperature and relative humidity have been reported to accelerate the breakdown of carotenes during fresh produce storage (Namita and Negi, 2010). When spinach was allowed to wilt, it lost almost 64% of its original carotenoids. Fresh green leaves of Amaranthus reportedly lost 85% of beta-carotene depending on storage conditions. In this same study packaged spinach retained higher beta-carotene than unpackaged (Namita and Negi, 2010).

*10.4.4.1 Impact of preservation and cooking methods*

WV are usually dried as a way of preserving them for future use (Masarirambi *et al*., 2010). Not many studies have been done on the changes in nutritional content of WV due to drying and to aging in storage. Some of these changes may be positive in that they lead to the formation of new beneficial compounds. People preserve by sun-drying raw vegetables and then cooking again or they cook, sun-dry store and then cook again when needed. The nutrient content of vegetables prepared in these ways has seldom been investigated. The norm is to base estimations on fresh raw samples which have been handled under laboratory conditions. In certain cases vegetable samples are preserved in nitrogen at harvest and then stored at -80$^{o}$C to preserve them if they cannot be analysed immediately. These conditions and this form of handling certainly do not represent what happens at household level, and is likely to overestimate the nutritional composition of these vegetables. Some storage of harvested WV before use is inevitable in the rural areas, e.g. vegetables harvested in the morning or afternoon are cooked in the evening or left over vegetables cooked the following day. The degradation of beta-carotene is thus inevitable. Nutritional composition and bioavailability studies would need to be conducted on these dried and re-cooked vegetables so as to accurately estimate how much nutrients people actually obtain from these vegetables. Open air and sun-drying resulted in 16% and 9% loss in beta-carotene in orange-fleshed sweet potatoes (Namita and Negi, 2010).

Cooking methods are known to affect the chemistry of prepared food (Namita and Negi, 2010; Du *et al*., 2000; Mepba *et al*., 2007). Stir-frying and boiling were reported to diminish the anti-nutritional factors phytate, polyphenols and oxalate but they also destroyed bioavailability promoting factors like ascorbic acid (Du *et al*., 2000). In an extensive study by Mepba *et al*. (2007) blanching and cooking resulted in statistically significant reductions in potassium, sodium, zinc, iron and phosphorus contents of Amaranthus, tomatoes, fluted pumpkin, spinach, slippery vine and cocoyam leaves. In the study by Mepba *et al*. (2007) sun-drying of wild leafy vegetables had variable effects but led to significant reduction in vitamin C (44.5% - 47.5%). These losses were less than losses due to cooking which were between 64.3% and 67.5%.

From the foregoing, the importance of establishing some area specific standard values based on samples collected from WV meals ready for eating is apparent. From these standard values, losses in nutrients due to different handling and post-harvest techniques can be estimated. Area specific standards are necessitated by the variations in cooking methods of the same foods from place to place. Although simulating cooking methods in the laboratory could possibly lead to increased accuracy in reported values for the nutrient content of food, it will not substitute for sampling meals from the areas they are cooked before conducting the necessary food tests.

*10.4.4.2 Challenges related to laboratory sample preparation*

Methods of preparation vary from place to place and household to household. These methods are not accurately simulated in the analytical laboratories resulting in an overstating of the nutritional composition than is actually available for absorption. Some methods involve boiling and decanting of the water to get rid of astringent taste resulting in the loss of nutrients. Kumari *et al*. (2004) reported that cooking leafy vegetables in iron utensils led to increased total iron and bioavailable iron compared to uncooked vegetables and those cooked in other types of utensils such as aluminium and stainless steel. Uusiku *et al*. (2010) also then proposed that this same should also apply to WV (which they referred to as African leafy vegetables). Cooking has also been reported to enhance the availability of some micronutrients but decrease the availability or even destroy some other micronutrients as observed by Agte *et al*., (2000) who suggested that green leafy vegetables have good potential to supplement iron and beta carotene either cooked or raw but in their cooked form were not good supplements of riboflavin, folic acid, zinc and copper (Agte *et al*., 2000).

*10.4.5 Challenges related to interpretation of findings*

As noted by Lewu and Mavengahama (2010) the potential of WV to accumulate micronutrients may be understated. This arises from the observation that most comparisons with cultivated vegetables are not standardised; cultivated vegetables are grown under well managed growth conditions and with fertiliser application but WV just grow on their own without care. Thus, values reported for WV are not always optimal as most work has involved collecting from the wild and analysing and then comparing to conventional vegetables that were grown under optimal conditions with fertilisers and adequate moisture and harvested at the right time.

## 10. 5 Conclusions

There is wide variability in the reported chemical and nutritional composition of WV from different studies and different geographical areas. This variation is also observed in studies on conventional vegetables. The accuracy of characterising the chemical composition of WV is confounded by many environmental and technical factors. There is a general agreement among researchers that WV are rich in mineral and other essential organic nutrients, yet results from different parts of the world are not always comparable due to absence of standardised protocols. Finally, more research is needed on different agronomic and nutritional aspects of WV so as to enhance their food value.

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# CHAPTER 11

## The role of wild vegetable species in household food security in maize based subsistence cropping systems[22]

### 11.1 Introduction

Wild vegetables (WV) are an important source of food mainly in the rural parts of South Africa (Jansen van Rensburg *et al*., 2007; Modi *et al*., 2006; Vorster *et al*., 2007; Vorster *et al*., 2008; Shackleton, 2003). This is especially so in the maize (*Zea mays* L.) based subsistence farming sector where they are eaten as relish to accompany phutu which is prepared from maize meal. The emphasis on maize based cropping systems is premised on the knowledge that the staple main maize meal porridge (phutu) invariably requires relish to complement it and that among the most impoverished groups of the rural population WV assume the role of main relish. Some of the commonly occurring and important WV in selected regions of South Africa are presented in Table 11.1. A comprehensive discussion on the occurrence and distribution of other and lesser utilised WV in different parts of South Africa can be found in Jansen van Rensburg *et al*., 2007; Maanda and Bhat, 2010; Steyn *et al*., 2001 and Odhav *et al*., 2007.

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**Table 11.1** Some commonly occurring vegetables in parts of KwaZulu-Natal and the Limpopo Provinces of South Africa.

| Scientific name | Local names in KwaZulu-Natal Province | Local names in Limpopo Province | Season[1] available |
|---|---|---|---|
| *Amaranthus hybridus* | imbuya | vowa,thebe | all year |
| *Amaranthus spinosus* | imbuya | imbuya | summer |
| *Bidens pilosa* | uqadolo | mushidzhi | all year |
| *Chenopodium album* | imbilikicana | umbicani | spring |
| *Cleome gynandra* | | murudi | all year |
| *Cleome monophylla* | isiwisa | - | - |
| *Momordica foetida* | intsungu | nngu | summer |
| *Galinsoga parviflora* | isishukeyana | - | - |
| *Solanum nigrum* | umsobo | umsobo muxe | summer |
| *Corchorus olitorius* | ligusha | - | - |
| *Corchorus trilocularis* | - | delele | summer/autumn |

Adapted from Steyn *et al*., 2001; Odhav *et al*. 2007; and Lewu and Mavengahama, 2010. [1] The seasonality is reported for Limpopo Province only. KwaZulu-Natal has both Mediterranean and tropical climates; therefore the occurrence of the wild vegetables varies greatly.

The importance of WV has, until recently, been largely unrecognised and unacknowledged by agricultural policy makers (Rubaihayo, 2002; Shackleton, 2003), researchers and nutritionists alike. The main valuable attribute of these WV plant species about which many researchers are in agreement is their high nutritional (micronutrient) content (e.g. Steyn *et al*., 2001; Nesamvuni *et al*., 2001; Odhav *et al*., 2007). The ability of any food to provide nutrients is one of the important components of food security. WV presently contribute to the alleviation of household food insecurity (Legwaila *et al*, 2011) but this contribution could be increased through the promotion of their consumption and their integration in the maize based cropping systems at household level in subsistence farming systems in South Africa in particular, and in smallholder cropping systems in general.

There have been many attempts to define the concept of food security. The FAO (2008) definition which says food security is "*a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and* *nutritious food that meets their dietary needs and food preferences for an active and healthy life"* is widely used. Four key dimensions of food security have also been identified namely: food availability, food accessibility, food system stability and food utilization (FAO, 2008).

Prior to the 1970s, food security mainly related to national food production and international trade (Devereux and Maxwell, 2001; Maxwell and Smith, undated), but the concept has since been expanded to include households' and individuals' access to food. Generally, looking at food security from a wider (national/regional) viewpoint has the effect of masking or concealing the shortages or deprivation at household level. This is because commercial agriculture, which uses irrigation infrastructure, inputs such as fertilisers, pesticides, labour and appropriate farming knowledge, can lead to high yields and contribute to food security at national level. Several reports have indicated that South Africa is food secure at national level (e.g. Koch, 2011; Altman *et al*., 2009) but there is variation on the reported status of household food security. Studies on household food security in South Africa use a range of indicators and measurement tools. Consequently, reported levels of food insecurity vary widely across studies. Household food insecurity levels ranging from 35 to 73% have been reported (Hendriks, 2005). Jacobs (2009) estimated that roughly 85% of the population cannot afford to purchase a balanced diet providing sufficient energy. High levels of chronic malnutrition among infants and young children are further evidence that food insecurity is a significant problem at household level.

Food security goes beyond food availability and accessibility, it also includes whether the diet is balanced – that is, whether all the essential nutrients are available in their correct proportions (FAO, 2008). We argue that if a household has enough maize to provide adequate *phutu* throughout the year but struggles to get relish most of the time, such a household cannot be regarded as food secure since the absence of relish means that the maize meal will not be palatable and therefore may not be eaten in sufficient quantities to give an adequate diet. Furthermore, foods from the wild such as indigenous vegetables, fruits, mushrooms and bush meat which contribute to the rural household food basket (Legwaila *et al*., 2011; Bharucha and Pretty, 2010) are usually not included in national foods baskets (Bharucha and Pretty, 2010). Without a better understanding of these dimensions of food insecurity at household level, it is difficult to estimate total food insecurity and understand the causes of vulnerability to food insecurity among rural households.

**11.2 Problem statement**

There is a growing recognition that the present problems with food insecurity and poor nutrition need an integrated approach, which acknowledges the complex and integrated nature of rural poverty (Chambers, 1990) so as to achieve synergies through the integration of various disciplines in mitigating the problem (see McLachlan and Garrett, 2008). We posit in this paper, that the integration of WV cultivation in the subsistence farming sector in South Africa can contribute to the alleviation of household food insecurity. There is a growing body of literature from various parts of the world on the role of WV in household nutrition, mostly indicating that these species are important as a food source (Bharucha and Pretty, 2010; Jansen van Rensburg *et al*., 2007; Modi *et al*., 2006; Vorster *et al*., 2007; Vorster *et al*., 2008; Shackleton, 2003; Flyman and Afolayan, 2006a; Legwaila *et al*., 2011). Maunder and Meaker (2007) have concluded that the combined effort of nutritionists and agriculturalists is needed to promote and enhance the utilisation of WV as some of the crops consumed at household level. Similarly, in a study on the utilisation of these vegetables among the *Vhavhenda* people, Nesamvuni *et al*. (2001) encouraged health educators to promote the nutritional advantages of WV. There are knowledge gaps regarding the importance, abundance, and ease of cultivation of WV and even on the need to domesticate and cultivate them, yet not much empirical evidence is available to support or rebut these observations. During some of our research cohort meetings, some colleagues have argued that WV are widely and freely available and abundant and therefore there is no need to cultivate them. They argue that these vegetables are only needed in smaller quantities and the naturally occurring amounts should be adequate. Others have raised doubts as to the feasibility of completely domesticating these plant species and question whether they are actually important in household food security in terms of food bulk.

Some researchers have reported that rural people perceive the populations of WV to be in decline (Shackleton, 2003; Vorster *et al.*, 2008). Our own observations and experiences are that even for seemingly abundant wild species such as *Amaranthus* (pigweed) and *Bidens pilosa* (black jack), people do not indiscriminately consume all of the available varieties but select, depending on certain specific (un)desirable characteristics like leaf hairiness, astringency (bitterness) and leaf size (which influences ease and speed of gathering/harvesting). As a result, not all that is available is consumed. There is still need for researchers to closely interact with people so as to clearly understand people's perceptions and utilisation patterns at household level with respect to WV. It is also argued here that if these vegetables are mostly used in times of food shortage in the home, then there is also likely to be a shortage of other ingredients and other seasoning additives that make any relish tasty. As a result both adults and children will come to associate these vegetables with poor taste, which might not be an inherent feature of the vegetables themselves, but a result of inadequate ingredients.

The goal of this paper is to critically review the role that WV play in household food security in maize based subsistence cropping systems. It also highlights some of the generally agreed roles and the threats to WV in the literature. The following questions are explored.

1. What are the roles of WV in household food security in poor rural households?
2. What is the nutritional composition of WV and what factors contribute to the bioavailability of these nutrients?
3. What are the threats to WV utilisation?

### 11.3 Methods used for literature search

This paper is an outcome of a broader trans-disciplinary (Td) study, which uses different methods to generate information. Some of the knowledge was generated during discussions with colleagues during our regular Td meetings. For this particular critical review the literature was obtained from various sources. The search was limited to peer-reviewed papers published in journals. A comprehensive search was conducted by subject, using the Google search engine, on the following search terms: “wild vegetables” or “wild vegetables in South Africa” or “indigenous vegetables” or “food security in South Africa” or “household food security in South Africa.” Through an analysis of the content of returned entries, papers were selected based on their relevance to the subject of this review. The records were then analysed and those records that were journal publications were assessed further. Forty papers were considered relevant and included in the review.

## 11.4 Roles of wild vegetables in subsistence farming systems

### *11.4.1. They are an integral component of the main meal of the day*

WV species integrated as part of the main diet have a role in the management of hunger and specifically micronutrient deficiencies. Their main role is as relish (Oniang'o *et al*., 2003), that is, they are used as complement for staple diets (such as phutu, pap, sadza or ugali), made mainly from maize meal and sometimes other cereals such as sorghum (*Sorghum bicolor* L. Moench) and pearl millet (*Pennisetum typhoides*). They are thus an integral component of the main meal of the day as usually they are the main relish with which the staple maize dish is eaten. They are usually prepared as the preferred relish on their own or as substitute for exotic vegetables in stews and soups in cases where meat and other vegetables cannot be afforded. However, where an alternative relish is available, they can be referred to as a supplement (Kepe, 2008). Relish is an indispensable part of the African diet (Smith and Ezyaguirre, 2007; Oniang'o, 2003) since the main staple cereal is not normally eaten in the absence of relish. Thus the presence of relish directly impacts on the consumption of the bulk of the main staple even though the relish is required and consumed in smaller proportions relative to the staple.

It is evident from the foregoing that WV play a significant role in food system stability at the household level. Food system instability is determined by the temporary or permanent loss of access to the resources needed to consume adequate food (FAO, 2008). The temporal variability in the occurrence of WV due to their seasonal availability in response to the changes in seasons of the year certainly causes instability in local rural food systems, especially among those vulnerable groups who totally depend on them for relish. This has been reported by Modi *et al*., 2006; Vorster *et al*., 2007; Shackleton, 2003; Lewu and Mavengahama, 2010, 2011).

### *11.4.2 Nutritional role*

One attribute of WV about which there is general agreement among researchers is their potential to combat 'hidden hunger' (Tisdale *et al*., 1990; Harvestplus, 2011).

This is especially important among low income earners and the rural population (Lewu and Mavengahama, 2010) as the vegetables are not purchased. The nutritional composition of WV has been, and continues to be, characterised and they generally have been reported to be rich in micronutrients especially beta carotene, zinc, and iron, the principal nutrients whose absence from a diet results in 'hidden' hunger. Several studies conducted on indigenous vegetables have suggested that they generally have higher levels of various nutrients than the conventionally cultivated species (Flyman and Afolayan, 2006b; Ndlovu and Afolayan, 2008; Ohdav *et al.*, 2007; Steyn *et al*., 2001; Nesamvuni *et al*., 2001). Micronutrient malnutrition affects more than half of the world population, particularly in developing countries (WHO, 2000). In 2000, the World Health Report identified iron, vitamin A, zinc and iodine deficiencies as the most serious health constraints worldwide (WHO, 2000; Faber and Wenhold, 2007). Besides nutritional benefits, it has been suggested that the utilisation of these vegetables represents significant savings of cash in the household (Shackleton, 2003).

*11.4.2.1 Nutritional challenges of wild vegetables*

More research needs to be conducted on the ability of WV to contribute nutrients to the body. This is because research has suggested that nutrients from WV may not be bioavailable. The food security concept of food utilization goes beyond food use and includes how a person is able to absorb essential nutrients from the consumed food (FAO, 2008) and includes the concept of bioavailability. The bioavailability of nutrients is influenced by the presence in a meal of substances that either promote or inhibit absorption of nutrients by the gut (Lonnerdal, 2003; Gupta *et al*., 2006). These substances, which include phytate, oxalate and polyphenols are variously called anti-nutrients or anti-nutritional factors. They occur not only in WV but also in cultivated vegetables and fruits (oxalate), cereal and legume seeds (phytate) and beverages such as tea and coffee (polyphenols) (White and Broadly, 2009). It is estimated that only about 25% and 5% of the zinc in cereals and legumes, respectively, is bioavailable.

The bioavailability of the nutrients in WV has not been widely characterised. WV (and other foods) may be rich in mineral nutrients but these nutrients may not be easily available (bio-availability) due to anti-nutritional substances such as phytate and tannins which bind zinc, calcium and iron. If WV are mixed with other foods in the diet their anti-nutrients could render the micronutrients from the staples unavailable. However, as noted earlier, anti-nutrients also occur in beverages like coffee and tea and have therefore been present in diets for a long time.

### *11.4.3 Dietary diversity and cultural value*

The widely observed practice of mixing several WV species in one cooking vessel highlights their contribution to dietary diversity in terms of more vegetable types as well as in terms of choice of relish. Although most researchers have emphasized the superior nutritional composition of these species, this is not their only merit. There are other reasons behind the use of these species. It is not uncommon for the urban wealthy to be found visiting certain places where ethnic (traditional) foods are prepared, looking especially for these vegetables and other traditionally prepared meals (as alluded to by Kepe, 2008). They provide variety to otherwise monotonous cereal based diets (see Michaelsen *et al*., 2009; Maholtra and Passi, 2007). Providing different types of these WV can reduce this monotony by adding different tastes and colours to diets.

Although edible indigenous plant species have been utilised as food for centuries (Vorster *et al*., 2008; Adebooye and Opabode, 2004) current research has indicated that the use of WV in South Africa is in decline (Steyn *et al*., 2001; Modi *et al*., 2006). Flyman and Afolayan (2006b) have suggested that reliance on introduced exotic vegetables was the primary reason for the decline in Southern Africa. Lack of knowledge about nutritional composition, cooking methods and ways of preservation have also been suggested as reasons for low use of WV (Flyman and Afolayan, 2006b). Mnzava (1997) referred to `strongly localized importance’ as also reducing utilisation. This localized importance has also been alluded to by Jansen van Rensburg *et al*. (2007) who reported that although *Corchorus olitorius* (Jews mallow/ wild okra) occurs in Limpopo, KwaZulu-Natal and Eastern Cape, it is only consumed in Limpopo because people in the other provinces do not like its sliminess. Rubaihayo (2002) and Vorster *et al*. (2008) have suggested that the indigenous knowledge base of these vegetables has been eroded due to environmental and socio-cultural changes brought about by migration of labour, increased urbanisation and the promotion of cash crop farming instead of subsistence farming. Bharucha and Pretty (2010) have noted that food security is presently dependent on only a narrow variety of cultivated species.

*11.4.4 Security against food shortages*

Although they carry a 'food for the poor' and 'famine food' tag for some groups, the fact remains that WV are indeed an important last resort during famine. For some rural groups mired in the deprivation trap and perpetual poverty WV are substitutes for food crops (Kepe, 2008). There are some groups in society who would not ordinarily eat these vegetables under circumstances of adequate food availability but would consume them under difficult conditions of droughts and famines. It is possible that for some people who are in poverty these foods become such a part of their diets that even when circumstances change for the better, the attachment to these foods does not go away. Thus a drought induced famine would have social-cultural effects on wild vegetable use as suggested by Bharucha and Pretty (2010).

*11.4.5 Farm level agro-biodiversity and resilient local food systems*

WV increase agro-biodiversity at the household level. This agro-biodiversity helps in buffering against the accumulation and multiplication of pests and diseases, provide important cover for the soil at the edges of the fields or fault lines in the field which are prone to erosion – their roots together with other weeds hold the soil in place and reduce raindrop impact. This is especially true for the widely occurring species such as black jack (*Bidens pilosa*) and pigweed (*Amaranthus hybridus*). The hardiness of WV ensures that they thrive in both drought and flood times and as a result they are available during harsh environmental conditions when most cultivated crops would have failed. They are thus resilient and their increased utilisation and cultivation would introduce resilience in the food systems of most subsistence farmers (see Bradford, 2010).

## 11.5 Threats to wild vegetables

The current manner of use of WV relies on harvesting without cultivation, a practice that may be regarded as exploitative and therefore unsustainable in view of increasing population density. It could lead to genetic erosion (see Flyman and Afolayan, 2006a) and possible loss of biodiversity (Shackleton, 2003; Bharucha and Pretty, 2010). Decline in the wild population of some indigenous vegetables has already been reported (Shackleton, 2003). Further, the utilisation is also unsustainable in that the benefiting people have no control over availability as they do not cultivate these vegetables. Thus, availability is unpredictable and variable. An alternative to this utilisation approach is the integration of indigenous vegetables in cropping systems. This could result in increased agro-biodiversity. Increased genetic diversity has been shown to support food security as well as buffering against unfavourable environmental conditions, pests and diseases (Venter *et al*., 2007; Moore and Raymond, 2006).

Kwapata and Maliro (1995) have suggested that the decline in wild vegetable use is due to chemical elimination as they are considered as weeds. This is especially true in Southern Africa where agricultural education in both commercial and communal areas is aimed at cash crop production. This type of farming promotes mono-cropping and mono-culture and emphasizes the eradication of any other plant species in the field as they are regarded as weeds. This attitude towards WV still prevails among researchers and extension workers who continue to advise farmers to remove them from their fields (Vorster *et al*., 2007; Shackleton, 2003).

### 11.6 Some research needs regarding wild vegetables

The attitudes and perceptions of people towards WV are not yet fully understood. The willingness of people to formally adopt these vegetables as cultivated crops may be influenced by perceptions, cultural beliefs, values and social stigmas attached to them. Do people view these plant species as important vegetables, or, as suggested by Shackelton *et al*. (2006), just as `safety nets' to be used when there is not enough food during droughts, famine or lack of money to purchase exotic vegetables? There is thus need for more in depth participatory studies on the indigenous knowledge systems about these species as well as on the current importance of these vegetables in the household economy. Studies on the nutritional composition of WV are required. The amounts of nutrients reported for the same species from different studies vary widely (Uusiku *et al*., 2010). The question then is what factors affect the nutritional composition of these vegetables? More controlled experiments on aspects such as effect of soil type, effect of fertiliser amount and type, and age of harvesting on the nutritional composition of WV need to be conducted. The bioavailability of micronutrients also needs to be determined for cooked vegetables as most of the available data are on raw samples (Uusiku *et al*., 2010). The abundance and diversity of these vegetables need to be determined. Diversity studies are especially important as a preliminary step in breeding of these species for desirable traits such as low anti-nutrients and low astringency, high micronutrient content as well as high yield of the edible parts. The potential of these vegetables to contribute to agro-biodiversity at farm (household) level through intercropping them with other crops also needs to be explored. In addition, the possibility of commercialising WV production and make them available to urban populations needs to be researched.

## 11.7 Conclusions

Wild vegetables have various roles in subsistence farming systems. They are a source of food and are particularly rich in micronutrients. They are consumed as relish to accompany the main cereal staple dish. They also contribute to dietary diversity and agro-biodiversity at the household level. Major threats to WV use include utilisation without cultivation and their elimination from cultivated fields as weed species which leads to the depletion of the natural population. Further research on various aspects of WV is needed. Peoples' attitudes and perceptions, the nutritional value of WV, morphogenetic characterisation, plant improvement and agronomic research on soil fertility requirements and ability to be intercropped are some of the areas that require further investigation.

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# CHAPTER 12

## General discussion, conclusions and recommendations

### 12.1 Discussion

This study primarily focused on a particular section of the farming community in South Africa; namely the subsistence farming sector. This is a sector with similar socioeconomic circumstances generally characterised by low input agriculture with no mechanisation. The majority of the areas have marginal and erratic rainfall and inherently infertile soils; thus exposing farmers to frequent crop failures. The mixed system can be described as maize based mixed cropping. Most of the farmers grow maize as the staple crop. This maize is also supplemented by other cereals such as millets, sorghum and rice. Other starchy supplements include amadhumbe (*Colocasia esculenta*) and cassava (*Manihot esculenta*). It is in such a context that we sought to understand the current and potential role of some edible crop species variously named as wild vegetables, semi-domesticated, naturalised and African leafy vegetables, among other names.

The research revealed that the naming and identification of these vegetables was variable and not standardised, especially among researchers. This is because although some of these species have been around for many centuries now, they are recorded as having originated from other parts of the world and therefore are indigenised or naturalised species. Thus the origin of a plant cannot be known from face value, it would require trained botany scholars to classify it correctly. Some of these species are now partially domesticated either by deliberate human efforts of seed selection and retention or by their mere association with cultivated lands.

The literature review studies (Chapters 1; 3; 10 and 11), and the survey study (Chapter 5) provided evidence that wild vegetable species are indeed important in the diets of smallholder famers. Their importance is mainly as relish to accompany and complement the staple main maize dish. Both the literature reviews and the survey study further provided insights into the perceptions and attitudes of different age groups and gender regarding wild vegetables. The elderly recognised and appreciated the importance of wild vegetables as foodstuffs whilst the youths were reported as being indifferent to them. The vegetables are also generally associated with poverty.

The field soil and agronomic studies indicated that these vegetables respond positively to improved agronomic production practices, thus they are amenable to domestication. The micronutrient and macronutrient levels changed with the addition of soil amendments. The positive yield response to soil amendments, particularly to cattle manure means that smallholder farmers can use locally available fertilisers to grow these vegetables. It also means that where there is need to supplement amounts gathered from the wild through cultivation, manure can be added to improve yields per given area. The finding that Swiss chard was able to take up more of Zn and Cu from the soil compared with the two wild vegetables (C. *olitorius* and *Amaranthus* sp.) needs to be followed with a much wider study involving more wild vegetables and more exotic vegetable species so that a database of the responses of these species is obtained. For now, it would appear that encouraging dietary diversity is the most viable option in utilising leafy vegetables to alleviate micronutrient deficiencies in the diets. As discussed in Chapters 9 and 10, cultivation efforts are still hampered by physiological issues which include germination problems and unpredictable flowering patterns among other problems. Dormancy and poor germination are common features of most semi domesticated species and are only eliminated after many generations through selection and breeding efforts leading to the domestication of these species. A species such as Amaranthus however has been observed not to have germination problems. The problem of bolting observed in C. *gynandra* presents challenges for farmers and researchers; for farmers in terms of reduced yields and wasted nursery time and for researchers to come up with varieties that do not flower prematurely.

The study had its own challenges and limitations. It being situated within a transdisciplinary (Td) programme and therefore premised on a Td research paradigm places a sort of burden of expectations on the part of the researcher. There is a temptation to tailor make the research to meet the defined tenets of Td-ness. This study had to be done as a PhD project and by so doing this somewhat removed it already from the wider problem. The argument however is that the awareness of the researchers of the Td nature of the problem being researched enabled the making of informed decisions and choices in the omission of certain tenets that are regarded as essential to Td. Such a choice would only be made if it was the last resort; this is important because this is a choice and not an omission as would be done when one is not aware of the complex interdependency of the various disciplines.

Intended activities such as joint problem framing before finalising the project topic could not be undertaken due the nature of the programme. The proposal development is done in residence and during this time there is no chance of visiting the research sites before the issuing of ethical clearance. Funding for field work was also one of the constraints. As a result whilst researchers were aware of this requirement for future studies which are not time constrained, this nevertheless became a weakness of this study. However, the author grew up in the subsistence farming sector circumstances very much similar to those described in this study and has passively gathered knowledge on the subject for the greater part of his life. He thus also drew from his experience and is convinced that the issues researched in this study are relevant.

Having said this, the present study is just a contribution to the research on indigenous vegetables. More research is still to come in the area of wild vegetables. The importance of these plant species is increasingly being recognised by researchers and policy makers. This is confirmed by the setting up of research units dedicated to studying indigenous vegetables by the national research institutes such as the Agricultural Research Council in South Africa and international research organisations such as Bioversity international. The setting up of an office at the University of Zululand by the Agricultural Research Council of South Africa for the promotion of wild vegetables in northern KwaZulu-Natal is indicative of the growing recognition of the importance of wild vegetables in this part of the country. Besides our own survey in northern KwaZulu Natal in this present study which confirmed the importance of wild vegetables, there is a growing body of literature on wild vegetables which has affirmed their importance

## 12.2 Conclusions

The following conclusions can be drawn from this present study:

1) The perceptions of different groups of people regarding wild vegetables are varied. Both literature studies and our survey study have implied that women are mostly involved in the gathering of these vegetables and therefore value them more. Younger people associate wild vegetables with poverty and backwardness. Some academics believe that wild vegetables are widely available and therefore there is no need to research them or promote their use.

2) Wild vegetables play an important role in the daily lives of most rural people in northern KwaZulu – Natal. They are consumed as a relish although they are not being cultivated; their methods of acquisition being gathering from homesteads, cultivated lands, the veldt and woodlands. These vegetables are also believed to be medicinal, although there is variability in the knowledge of the ailments treated. Wild vegetables are abundantly available during summer and there is a decrease, even no-availability, during winter and the dry season leaving some vulnerable people who rely on them in a state of food deficit.

3) Wild *C. olitorius* varieties with different seed sizes require a different exposure time to heat treatment methods to break impermeable seed coat dormancy. Steeping medium to large sized seed of wild *C. olitorius* in 80$^{o}$C hot water for 10 minutes and in boiling water for 10 seconds resulted in the highest germination percent. However, there is a need for the characterisation of different wild *C. olitorius* varieties for further differentiation into their morphological classes. *Cleome gynandra* is prone to premature flowering. This premature flowering leads to drastic reduction in utilisable leaf and shoot yield. The continuous removal of the flowers leads to increased utilisable leaf yield. The application of incremental amounts of nitrogen top dressing results in increased leaf yield in C. *gynandra.*

4) The different vegetables species investigated demonstrated different abilities to concentrate Cu and Zn in the order Swiss chard > *Amaranthus* sp.> C. *olitorius*, and that they responded to soil applied micronutrients by taking up more from the soil as more was supplied but up to a certain point. Thus there was variable uptake of elements by the species.

5) C. *olitorius* growth parameters measured responded significantly to the application of both basal and top dressing soil amendments. Use of either manure or NPK was advantageous to growing without fertiliser. The response of C. *olitorius* to LAN levels greater than 200 kg/ha and different rates of basal fertilises needs to be investigated further, preferably under on-farm conditions.

## 12.3 Recommendations for future research.

### *12.3.1 Genetic evaluation, taxonomic and breeding studies*

Genetic evaluation will facilitate establishment of genebanks from where breeders can obtain the accessions to breed improved varieties. There is very little information on genetic variability, areas cultivated or propagation methods. Non-availability of genetically improved seed has been reported to be a major constraint to the few wild vegetables that are presently under cultivation elsewhere (Adebooye *et al*., 2005). Morpho-genetic evaluation could also aid in selection for desirable traits. For example, if astringency, (which is an undesirable trait) can be linked to certain morphological traits, then selection against astringency becomes simplified. Morphological descriptors for wild vegetables are also not available and this makes it difficult for morphological characterization. There is need, therefore, for a systematic and comprehensive genetic evaluation of all the wild vegetable species to facilitate crop improvement and to develop gene banks and information databases for use by agricultural scientists.

The local taxonomy of wild vegetables varies greatly but they are collectively known as *imfino* in isiZulu (Jansen van Rensburg *et al.*, 2007). However, the name *imfino* is also used to identify certain species of these wild vegetables as well as domesticated vegetables like cowpeas (*Vigna unguiculata*) and pumpkins (*Cucurbita* spp. For instance in our preliminary studies around Melmoth in northern KwaZulu-Natal (Unpublished data), respondents identified *Bidens pilosa* as *imfino* yet in other villages it is known as *uqadolo* and the name *imfino* is a collective term for all wild vegetables. This is a clear indication that local nomenclature of the same species varies from place to place or between communities in the same locality. It is important that wild vegetables are correctly identified by their botanical and local names. This characterisation provides the basis for identifying the variation in nutrients and health protecting traits among cultivars within a species (Smith and Ezyaguirre, 2007).

*12.3.2 Agronomic, seed biology and germination studies*

The potential of these vegetables to contribute to agro-biodiversity at farm (household) level through intercropping them with other crops also needs to be explored. Agronomic evaluation can only lead to better understanding of the best cultural practices for increased yields and improved nutritional and medicinal properties. There is also little information on the response of these species to fertilisers and other agronomic practices. Studies in other crops have indicated that mineral fertiliser can lead to improved quality in terms of proximate and chemical composition but the effects of fertiliser on chemical composition of wild vegetables is not known due to lack of research.

Several constraints to propagation and multiplication of indigenous vegetable species have been identified. Lack of seed availability, variability in seed quality and lack of seed selection for uniformity of desired traits are some of the constraints that require urgent research inputs (Smith and Ezyaguirre, 2007). Opabode and Adebooye (2005) have reported biological constraints which may hinder germplasm conservation efforts. These include numerous morphotypes for *Corchorus olitorius* L and *Celosia argentea* L, seed dormancy in *Launea taraxicifolia,* low seed viability in *Solanecio biafrae* and recalcitrant seed in *Telfairia occidentalis.* There is a decline in the seed germination of *Telfairia occidentalis* when seed moisture is less than 40% and germinability is completely lost when moisture content falls below 30 %. There is need for comprehensive studies on seed biology to generate information on seed dormancy and germination requirements. This has implications for production of these species outside their habitats and during the off-season (winter).

*12.3.3 Processing and preservation studies*

The easy perishability of wild vegetables poses major challenges with their storage, distribution and marketing (Jansen van Rensburg *et al*., 2007; Medisa and Tshamekang, 1995). In South Africa, drying is the major method of processing leafy vegetables to make them available during periods of scarcity (Vorster *et al.*, 2007). Whilst drying solves the problem of perishability, it does not satisfy the needs of a large population of consumers, particularly urban dwellers who prefer freshly harvested vegetables (Smith and Ezyaguirre, 2007). It is also not known how prolonged cooking and drying affects the vegetables in terms of nutritional status and medicinal potential. In other vegetable species, especially the exotic cultivars, it is well documented that drying and storage for longer periods destroys vitamin C. Other constituents that are destroyed or altered are yet to be established.

The development, documentation and promotion of recipes would be an important tool in promoting these species among people who may not know how to cook these species but are willing to try them. We believe that it is not unreasonable to surmise that many people may have access to these species but have no knowledge about how they are prepared. This would especially target the urban population.

Improving taste in vegetable species that have a bitter taste is important. Vegetables such as *Cleome, Bidens* and *Mormodica* are very bitter as to be unpalatable. In an attempt to reduce the bitterness people boil the vegetables boil and throw away the water thereby losing valuable nutrients. Characterising the levels of anti-nutritional factors such as phytate, oxalate and tannins. These factors are known to bind Zn, Fe, Cu and Ca in unavailable forms reducing the absorption of the elements. This reduces the food value of foods that are otherwise rich in these elements.

*12.3.4 Field establishment, harvesting and on-and-off-season production studies*

Vegetables can be established either by direct seeding or transplants. The advantages of direct seeding are that there is no root disturbance and the plants do not have to go through a recovery period and suffer transplant shock. The major limitation of direct seeding is poor field emergence leading to sub-optimal plant densities. Transplanting has the benefit that the seedbed conditions can be manipulated to provide optimum growth conditions for seedlings. It also facilitates the growing of seedlings away from harsh environmental conditions and transplanting can be delayed if the conditions are not conducive for plant growth. The major limitation is that seedlings have to be hardened for them to be able to withstand post-transplant shock in the open field. Roots may be damaged during pulling at transplanting especially if the soil is the seedbed. There is need to assess the best establishment methods for wild vegetables, conduct plant density studies and also evaluate the performance of wild vegetables in crop mixtures with the staple crops found in northern KwaZulu-Natal. Harvesting studies also need to be conducted. Studies by Chweya (1995) indicated that harvesting stimulated more foliage growth in cowpeas and Cat's whiskers (*Cleome gynandra*). However there was no scientific explanation suggested for this observation. We postulate that the removal of the apical shoot during harvesting caused the removal of plant growth substances responsible for apical dominance thereby promoting the developing of lateral buds. More studies are needed in this area of physiology as well as studies on the effect of harvesting frequency and harvesting intensity on yield.

There is a dearth of literature on the response of wild vegetables to season of production as most of these species do not readily grow during winter in the sub-tropics. However, some of these wild vegetables are found on irrigated plots occurring as weeds even during winter. This could possibly be a case of well adapted accessions with potential for off-season production. These few naturally occurring accessions could be collected as potential germplasms for further evaluation for winter season production. There is need to explore ways of propagating these wild vegetables during the off-season so that fresh wild vegetables are always available (Vorster *et al*., 2007). A study by Modi *et al*. (2006) at Ezigeni, KwaZulu –Natal revealed that the availability of wild vegetables suddenly declined in May and became scarce between July and August and only increased as the season progressed from August to October. The sudden manner in which these vegetables become unavailable leaves many vulnerable families exposed to hunger between the months of May to November. There is, therefore, need to explore the feasibility of cultivating wild vegetables so that they can be grown throughout the year in order to ensure continuous availability

### *12.3.5 Chemical and nutritional composition studies*

The amounts of nutrients reported for the same species from different studies vary widely (Uusiku *et al*., 2010). The question then is what factors affect the nutritional composition of these vegetables? More controlled experiments on aspects such as effect of soil type, effect of fertiliser amount and type, and age of harvesting on the nutritional composition of WV need to be conducted. The bioavailability of micronutrients also needs to be determined for cooked vegetables as most of the available data are on raw samples (Uusiku *et al*., 2010).There is a need for chemical analysis of conventionally edible plants parts of these species. This study could be compared with other parts of the shoot. For instance, if the stem contains more nutrients than leaves then consumers would have to be advised to consume the young tender stem as well as the leaves. It is suggested that chemical analysis includes phenols, proximates, mineral elements, tannins and anti-nutritional factors like phytate. Vegetables may be rich in mineral nutrients but these nutrients are not easily available (bio-availability) due to anti-nutritional factors like phytate and tannins. Studies have shown that the mineral contribution of vegetables to human nutrition is limited due to the presence of anti-nutrients. The most common anti-nutritional factors in indigenous leafy vegetables are phytate, tannins, hydrocyanic acid and oxalic acid (Akwaowo *et al*., 2006). In plants, phosphorus is mainly stored in the form of phytate and is therefore abundant. Phytate has the ability to bind with polyvalent mineral ions like $Zn^{2+}$, $Fe^{2+}$ and $Ca^{2+}$ to form an insoluble precipitate. As a result of this precipitate, these ions are not absorbed into the bloodstream (Lonnerdal, 2003; Gupta *et al*., 2006). This suggests that while laboratory results might indicate that vegetable leaves are rich in certain elements, these elements will actually not be able to contribute to the nutrition of humans. Wild vegetables need to be characterized on the basis of anti-nutritional factors and where possible, molecular markers could be used to aid in the selection for low anti-nutritional levels and other undesirable characteristics.

*12.3.6 Studies on indigenous knowledge of medicinal uses of vegetables*

While chemical analysis may isolate the active ingredients that are responsible for the medicinal properties of wild vegetables, most of the knowledge available is based on the indigenous knowledge of the local people. For example, indigenous knowledge possessed by rural women in Kenya indicates that spider plant (*Cleome gynandra*) has several medicinal uses (Opole *et al.*, 1995). In some communities, it is believed that regular consumption of the leaves of spider plant by pregnant women eases childbirth by reducing the time of labour, helps them to regain health faster and stimulates milk production in lactating mothers (Kokwaro, 1976). The decoction made from leaves is believed to treat scurvy and marasmus, while sap from pounded leaves is squeezed into ears, nostrils and eyes to treat epileptic fits and malaria

(Opole *et al*., 1995). Besides medicinal properties, spider plant has also been implicated in insecticidal, anti-feedant and repellent characteristics (Verna and Pandey, 1987). Most wild vegetables are also used as folk medicines in South Africa. There is need to collect and document such information and conduct verification studies to facilitate the propagation and commercial production of the medicinally important wild vegetables

*12.3.7 Attitudes and perceptions towards wild vegetables*

The attitudes and perceptions of people towards WV are not yet fully understood. The willingness of people to formally adopt these vegetables as cultivated crops maybe influenced by perceptions, cultural beliefs, values and social stigmas attached to them. Do people view these plant species as important vegetables, or, as suggested by Shackleton *et al*. (2006), just as `safety nets' to be used when there is not enough food during droughts, famine or lack of money to purchase exotic vegetables? There is thus need for more in depth participatory studies on the indigenous knowledge systems about these species as well as on the current importance of these vegetables in the household economy.

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# APPENDICES

## Appendix 1 Articles submitted and prepared

1. Mavengahama, S., McLachlan, M. and de Clercq, W. 2013. The role of wild vegetable species in household food security in maize based subsistence cropping systems in South Africa. *Food Security* 5: 227 – 333.

2. Mavengahama, S., de Clercq, W. and McLachlan, M. 2013 Comparative trace element composition of three wild vegetable species in response to soil applied micronutrients. *Presented at the 17th International Plant Nutrition Council Colloquium, 19th – 22nd August 2013,* Istanbul, Turkey.

3. S Mavengahama. 2013. Effect of deflowering and nitrogen fertiliser on yield of cat's whiskers (*Cleome gynandra*). *Journal of Food, Agriculture and Environment Volume* 11: (Issues 3 & 4) October - December 2013. [In press]

4. Mavengahama, S., de Clercq, W. and McLachlan, M. 2013**.** Effect of soil amendments on yield of the wild vegetable, wild okra (*Corchorus olitorius)* in northern KwaZulu-Natal, South Africa.

5. Mavengahama, S., McLachlan, M. and de Clercq, W. 2013. Challenges that can affect the accuracy and reliability of evaluating the micronutrient composition of wild vegetables under smallholder conditions in South Africa.

6. Mavengahama, S and Lewu, F.B. 2012. Comparative evaluation of the germination capability of three morphologically different wild okra (*Corchorus olitorius) accessions* from northern KwaZulu-Natal*. African Journal of Biotechnology* 11 (22): 6050–6054.

7. Lewu, F.B and Mavengahama, S. 2011. Studies on the utilization of wild vegetables in four districts of northern KwaZulu-Natal Province, South Africa. *African Journal of Agricultural Research* Vol. 6 (17): 4159–4165.

**Author contributions**: For articles 1 to 5, Mavengahama S performed the experiments and wrote the articles under the supervision of Dr W. de Clercq and Prof. M. McLachlan. For articles 6 and 7, Mavengahama S performed the experiments and wrote the articles under the supervision of Dr F.B Lewu.

**Articles presented at conferences**

S. Mavengahama, W de Clercq, M. McLachlan and G.E Zharare. Comparative Trace Element Composition of Two Wild Vegetable Species in Response to Soil Applied Micronutrient Fertiliser. 17th International Plant Nutrition Colloquium: Plant nutrition for nutrient and food security. 19 - 22 august 2013, Istanbul, Turkey

S. Mavengahama. Yield response of bolted spider plant (cleome gynandra) to deflowering and nitrogen top dressing. Poster presentation, Combined Congress 2013, 21 – 24 January 2013, University of KwaZulu-Natal, Westville Campus.

## Appendix 2 Questionnaire used for the survey study (Chapter 5)

| |
|---|
| Stellenbosch University<br>Faculty of AgriSciences<br>Department of Soil Science<br>Questionnaire on the Utilization of Indigenous Vegetables in KwaZulu-Natal province<br>South Africa |

Questionnaire identification

Latitude.........................................          Altitude...........................................

Longitude.........................................

Questionnaire/Respondent number:

| |
|---|
| |

INTRODUCTION

Good (morning/afternoon/evening), I'm ___________

___________________________________and I am conducting a survey on the utilisation of indigenous vegetables (*imfino*) in this area.

Your opinion and knowledge are very important in this research. To obtain reliable, scientific information we request that you answer the questions that follow as honestly as possible. There are no right or wrong answers. The area in which you live and you yourself have been selected randomly for the purpose of this survey. The fact that you have been chosen is thus quite coincidental. All the information you give to us will be kept confidential. You and your household members will not be identified by name or address in any of the reports we plan to write.

I also have a form with me that you can sign for to show that I have explained the purpose of my research and that you have agreed to be interviewed by me. However if you do not wish to sign it we can proceed with the interview after we have agreed verbally.

| | |
|---|---|
| Name of Interviewer/Enumerator | |
| Date | |
| Questionnaire number/Respondent | |

| | |
|---|---|
| number | |
| | |

UTILIZATION OF INDIGENOUS VEGETABLES IN Kwa ZULU- NATAL PROVINCE, SOUTH AFRICA.

1.1 Time taken (from)………………… (to)...............................

1.2 District ……………………………………………………...............

1.Municipality …………………………………………………........

1.4 Induna ………………………..……………..............................

1.5 Municipal Ward….…………………….……………....................

1.6 Traditional Sub- ward ……..……………….................................

2. Household information

2.1 How many members are in the household?.........................

2.2 Gender of household head …………………………….…..…

2.3 Age of household head ………………………………..…......

2.4 Educational level ……………………………………………....

2.5 Occupation …………………………………………….………..

2.6 Income/ month……………………………………………………

3. Access to Indigenous Vegetables.

**3.1** Do you eat indigenous vegetables?

| | |
|---|---|
| 1 | Yes |
| 2 | No |

**3.2** If no why?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Dislike them | Can't get them (not available) | Can't cook them | Don't know them | other |

Other (specify)________________________________________________________

________________________________________________________________________

3.3 If yes, which ones do you eat?

| Code | Name/ Response |
|---|---|
| 1 | Imbuya |
| 2. | Imbilikicana |
| 3. | Uqadolo |
| 4. | Isishukeyana |
| 5 | Intshungu |
| 6. | Intebe |
| 7. | Imbhati |
| 8. | Umayebabo |
| 9. | Other (Specify) |

Other (specify)__________________________________________________

______________________________________________________________

3.4 Which food do you eat imfino with?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Phutu | Pap | Rice | Bread | amadhumbe | cassava | Other |

Other (specify) __________________________________________

______________________________________________________________

3.5 Which part do you eat?

| Code | Name/ Response | 1 | Leaves | 2 | Stem | 3 | Roots | 4 | Fruit |
|---|---|---|---|---|---|---|---|---|---|
| 3.5.1 | Imbuya | | | | | | | | |
| 3.5.2 | Imbilikicana | | | | | | | | |
| 3.5.3 | Uqadolo | | | | | | | | |
| 3.5. 4 | Isishukeyana | | | | | | | | |
| 3.5.5 | Intshungu | | | | | | | | |
| 3.5.6 | Intebe | | | | | | | | |
| 3.5.7 | Imbhati | | | | | | | | |
| 3.5.8 | Umayebabo | | | | | | | | |
| 3.5.9 | Other (Specify) | | | | | | | | |

3.6 How do you obtain indigenous vegetables?

| Code | Response | |
|---|---|---|
| 1. | Buy | |
| 2. | Collect | |

3.7 If collected where from?

| Code | Response | |
|---|---|---|
| 1. | Own garden | |
| 2. | Veldt | |
| 3 | Wetlands | |
| 4 | Field | |
| 5 | Roadside | |
| 6 | Other (specify) | |

Other (specify)________________________________________________________

________________________________________________________________________

3.8 If purchased from where?

| | |
|---|---|
| 1 | Supermarket |
| 2 | Local market |
| 3 | Roadside vendors |
| 4 | Neighbours |

3.9 Which months of the year do you collect vegetables?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |

3.10 How often do you collect these vegetables per week?

| Code | | 1.Once | 2.Twice | 3.Thrice | 4.Other |
|---|---|---|---|---|---|
| 3.10. 1. | Imbuya | | | | |
| 3.10.2 | Imbilikicana | | | | |
| 3.10.3 | Uqadolo | | | | |
| 3.10.4 | Isishukeyana | | | | |
| 3.10.5 | Intsungu | | | | |
| 3.10.6 | Intebe | | | | |
| 3.10.7 | Imbhati | | | | |
| 3.10.8 | Umayebabo | | | | |
| 3.10.9 | Other (Specify) | | | | |

Other (specify)_________________________________________________________

________________________________________________________________________

3.11 Which indigenous vegetables do you use as medicines and for which ailments?

| Code | Name/Response | Tick | Ailment |
|---|---|---|---|
| 1 | Imbuya | | |
| 2. | Imbilikicana | | |
| 3. | Uqadolo | | |
| 4. | Isishukeyana | | |
| 5. | Intsungu | | |
| 6 | Intebe | | |
| 7. | Imbhati | | |
| 8. | Umayebabo | | |
| 9. | Other (Specify) | | |

Other (specify)____________________________________________________

________________________________________________________________

3.12 Which of the indigenous vegetables do you prefer mostly? Rank 5 of them in order of preference (1= most preferred 5 least preferred)

| Code | Name | Ranking | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 3.12.1 | Imbuya | | | | | |
| 3.12.2 | Imbilikicana | | | | | |
| 3.12.3 | Uqadolo | | | | | |
| 3.12.4 | Isishukeyana | | | | | |
| 3.12.5 | Intsungu | | | | | |
| 3.12.6 | Intebe | | | | | |
| 3.12.7 | Imbhati | | | | | |
| 3.12.8 | Umayebabo | | | | | |
| 3.12.9 | Other (specify) | | | | | |

Other (specify)____________________________________________________

________________________________________________________________

3.13 How long have you known these vegetables?

| Code | Response | |
|---|---|---|
| 1 | Less than a year | |

| | | |
|---|---|---|
| 2. | 1 -5 years | |
| 3. | From birth | |

3.14 Do you cultivate these vegetables?

| Code | Response | |
|---|---|---|
| 1. | Yes | |
| 2. | No | |

3.15 Which ones do you cultivate?

| Code | Response | |
|---|---|---|
| 1 | Imbuya | |
| 2. | Imbilikicana | |
| 3. | Uqadolo | |
| 4. | Isishukeyana | |
| 5 | Intshungu | |
| 6. | Intebe | |
| 7. | Imbhati | |
| 8. | Umayebabo | |
| 9. | Other (Specify) | |

Other (specify)____________________________________________________________

______________________________________________________________________________

3.16 What time of the year are they cultivated?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |

3.17 If cultivated where you do get seeds of these vegetables?

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Collect from own field | From NGOs | From friends | Purchase | From Dept of Agric | Other (specify) |

Other (specify)____________________________________________________________

______________________________________________________________________________

3.18 If you do not cultivate why?

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| There is no need | Do not know | Lack of seeds | Never thought | They are not | Do not eat |

| | | | | | |
|---|---|---|---|---|---|
| since they occur naturally | how | | of it | easy | them |

3.19 Do you process and store them or ensure that they will be available for future use?

| 1 | 2 |
|---|---|
| Yes | No |

3.20 If yes, how do you process them?

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Dry (uncooked) | Dry (cooked) | Place in fridge | Other |

3.21 How far do you travel to collect each of the vegetables these vegetables?

| Code | Response | 1 | 2 | 3 |
|---|---|---|---|---|
| | | Within the homestead | 500m to 1 km | >1 km |
| 3.21.1 | Imbuya | | | |
| 3.21.2 | Imbilikicana | | | |
| 3.21.3 | Uqadolo | | | |
| 3.21.4 | Isishukeyana | | | |
| 3.21.5 | Intshungu | | | |
| 3.21.6 | Intebe | | | |
| 3.21.7 | Imbhati | | | |
| 3.21.8 | Umayebabo | | | |
| 3.21.9 | Other (Specify) | | | |

Other(specify)________________________________________________________

______________________________ ______________________________

3.22 Do you collect these vegetables in the same field or area every year?

| Code | Response | |
|---|---|---|
| 1. | Yes | |
| 2. | No | |

3.23 Please comment on the population of these vegetables compared to previous years?

| Code | Response | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | | increasing | decreasing | Not changing | Never noticed | Don't know |
| 3.23.1 | Imbuya | | | | | |
| 3.23.2 | Imbilikicana | | | | | |
| 3.23.3 | Uqadolo | | | | | |
| 3.23.4 | Isishukelana | | | | | |
| 3.23.5 | Intshungu | | | | | |
| 3.23.6 | Intebe | | | | | |
| 3.23.7 | Imbhati | | | | | |
| 3.23.8 | Umayebabo | | | | | |
| 3.23.9 | Other (Specify | | | | | |

Other (specify)______________________________________________________

______________________________________________________________________

3.24 Do you have a home-garden?

| | |
|---|---|
| 1 | Yes |
| 2 | No |

3.25 Which vegetables do you cultivate?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| cabbage | spinach | rape | onions | tomatoes | Pumpkins | cowpeas | Beetroot | Other |

Other(specify)________________________________________________________

_______________________________________________________

3.26 Please comment on your preference between indigenous vegetables and those in the table above

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Prefer indigenous | Prefer those in above table | Prefer both | Other |

3.27 If you prefer indigenous what are your reasons for the above preferences?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|

| Easily available | Free | Healthy | Taste better | Easy to cook | Used to them | Part of culture/traditions | Other (specify) |
|---|---|---|---|---|---|---|---|

Other (specify)________________________________________________________________

________________________________________________________________

3.28 Who is responsible for collecting indigenous vegetables

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Older females | Young girls | Both young and elderly females | Adolescent girls and young women | Older men | Young boys | Adolescent boys and young men | Any family member |

3.29 If other family members do not collect and eat what are their reasons?

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | It's a woman's job | Busy with school work | Busy with other work | It's for old people | Don't like the taste | Prefer exotic vegetables like spinach | Other (specify) |
| 3.29.1 Older females | | | | | | | |
| 3.29.2 Young girls | | | | | | | |
| 3.29.3 Adolescent girls and young women | | | | | | | |
| 3.29.4 Older men | | | | | | | |
| 3.29.5 Young | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| boys | | | | | | | |
| 3.29.6 Adolescent boys and young men | | | | | | | |

3.30 How did you get knowledge about types of indigenous vegetables and how to cook them?

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Taught by parents | Observed parents | Passively as one grew up | From friends and neighbours | Learnt at school | Taught by grandparents |

3.31 How do younger people learn about indigenous vegetables?

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| We explain to them | They observe us | Taught at school | Other |

Other (specify)________________________________________________________

_____________________________________________________________________

3.32 Do you sell these vegetables?

| Code | Response | |
|---|---|---|
| 1. | Yes | |
| 2. | No | |

3.33 Who do you sell to?

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Passersby at roadside | At local market | Supply to shops/supermarket | Townships | Schools | Other (Specify) |

Other (specify)________________________________________________________

_____________________________________________________________________

3.34 Approximately how much do you collect per month in kilograms?

| Code | Response | |
|---|---|---|
| 1. | Less than 10kg | |

| | | |
|---|---|---|
| 2. | More than 10kg | |

3.35 How much money do you realise from selling of these vegetables per month

| Code | Response | |
|---|---|---|
| 1. | ( less than R 100) | |
| 2. | (R101- R200) | |
| 3. | (201- 300) | |
| 4. | ( R301- R 400) | |
| 5. | (R401-R500) | |
| 6 | >R500 | |

**3.36** Besides imfino which other foods collected from the wild do you eat as a family?

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

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.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

......................................................................

4. OCCURRENCE OF INDIGENOUS VEGETABLES IN RELATION TO SOILS, SOIL MANAGEMENT AND CROPPING

4.1 CROPS AND LIVESTOCK

**4.1.1** What crops do you grow in your fields?

______________________________________________________________

______________________________________________________________

______________________________________________________________

**4.1.2** What crops contribute the most to your food in the household?

Rank in order: 1 ____________________ 2________________________

3___________________ 4_________________________

5_______________________ 6_________________________

**4.1.3** Did you produce enough food for your family last year?

| | | | |
|---|---|---|---|
| Yes | | No | |

**4.1.4** Do you expect to produce enough food for your family this season?

| | | | |
|---|---|---|---|
| Yes | | No | |

**4.1.5** Do you own any livestock/animals?

| Type | Number | How are they fed? |
|---|---|---|
| Indigenous cattle | | |
| Cross bred cattle | | |
| Goats | | |
| Sheep | | |
| Pigs | | |
| Donkey | | |
| Poultry | | |
| Other: | | |

**4.1.6** Do you apply fertilisers to your crops?

| | | | |
|---|---|---|---|
| Yes | | No | |

**4.1.7** What types of fertiliser?

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle Manure | | compost | | poultry manure | | goat manure | | Sheep manure | | donkey manure | | other | | Mineral fertiliser | |

Other______________________________________________________

**Appendix 3 Soil physico-chemical analysis results for soil used in experiments in the study. (Chapters 6, 7 and 9)**

| Soil attribute | Units | Value |
|---|---|---|
| pH | - | 4.58 |
| Phosphorus | mg/L | 10.1 |
| Potassium | mg/L | 169.9 |
| Calcium | mg/L | 1432.3 |
| Magnesium | mg/L | 525.4 |
| Sodium | mg/L | 104.3 |
| Exchangeable acidity | cmol/L | 0.19 |
| Total cations | cmol/L | 12.55 |
| Acid saturation | % | 1.51 |
| Exchangeable sodium | % | 3.6 |
| Calcium/Magnesium ratio | - | 1.65 |
| Zinc | mg/mL | 2.4 |
| Copper | mg/mL | 2.7 |
| Manganese | mg/mL | 6.3 |
| Iron | mg/mL | 395 |
| Silicon | mg/mL | 28.54 |
| Clay estimate | % | 23 |
| Organic matter estimate | % | 4.3 |
| Volume weight | g/mL | 1.23 |

## Appendix 4 Analysis of variance tables for Chapter 7

Appendix Table 3.1 Analysis of variance table for leaf Cu content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 19.792 | 9.896 | 1.20 | |
| Vegetable | 2 | 218.311 | 109.155 | 13.28 | <.001 |
| Micronutrient | 3 | 619.676 | 206.559 | 25.13 | <.001 |
| Vegetable.Micronutrient | 6 | 143.416 | 23.903 | 2.91 | 0.031 |
| Residual | 22 | 180.867 | 8.221 | | |
| Total | 35 | 1182.061 | | | |

Appendix Table 3.2 Analysis of variance table for leaf Zn content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 9682. | 4841. | 0.88 | |
| Vegetable | 2 | 512531. | 256266. | 46.75 | <.001 |
| Micronutrient | 3 | 384722. | 128241. | 23.39 | <.001 |
| Vegetable.Micronutrient | 6 | 134079. | 22347. | 4.08 | 0.007 |
| Residual | 22 | 120603. | 5482. | | |
| Total | 35 | 1161617. | | | |

Appendix Table 3.3 Analysis of variance table for leaf Fe content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 195744. | 97872. | 14.43 | |
| Vegetable | 2 | 69945. | 34973. | 5.15 | 0.015 |
| Micronutrient | 3 | 13898. | 4633. | 0.68 | 0.572 |
| Vegetable.Micronutrient | 6 | 56487. | 9415. | 1.39 | 0.263 |
| Residual | 22 | 149267. | 6785. | | |
| Total | 35 | 485341. | | | |

Appendix Table 3.4 Analysis of variance table for leaf Mn content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 3006. | 1503. | 1.29 | |
| Vegetable | 2 | 212746. | 106373. | 91.38 | <.001 |

| | | | | | |
|---|---|---|---|---|---|
| Micronutrient | 3 | 4346. | 1449. | 1.24 | 0.318 |
| Vegetable.Micronutrient | 6 | 6132. | 1022. | 0.88 | 0.527 |
| Residual | 22 | 25609. | 1164. | | |
| Total | 35 | 251839. | | | |

Appendix Table 3.5 Analysis of variance table for leaf Ca content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 4.6380 | 2.3190 | 2.43 | |
| Vegetable | 2 | 9.2888 | 4.6444 | 4.86 | 0.018 |
| Micronutrient | 3 | 1.8033 | 0.6011 | 0.63 | 0.604 |
| Vegetable.Micronutrient | 6 | 5.1629 | 0.8605 | 0.90 | 0.512 |
| Residual | 22 | 21.0314 | 0.9560 | | |
| Total | 35 | 41.9244 | | | |

Appendix Table 3.6 Analysis of variance table for leaf K content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 0.3734 | 0.1867 | 0.47 | |
| Vegetable | 2 | 0.7211 | 0.3605 | 0.90 | 0.420 |
| Micronutrient | 3 | 2.6609 | 0.8870 | 2.22 | 0.114 |
| Vegetable.Micronutrient | 6 | 0.6319 | 0.1053 | 0.26 | 0.948 |
| Residual | 22 | 8.7823 | 0.3992 | | |
| Total | 35 | 13.1696 | | | |

Appendix Table 3.7 Analysis of variance table for leaf Mg content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 0.025089 | 0.012544 | 1.43 | |
| Vegetable | 2 | 4.185972 | 2.092986 | 237.78 | <.001 |
| Micronutrient | 3 | 0.015364 | 0.005121 | 0.58 | 0.633 |
| Vegetable.Micronutrient | 6 | 0.020428 | 0.003405 | 0.39 | 0.880 |
| Residual | 22 | 0.193644 | 0.008802 | | |
| Total | 35 | 4.440497 | | | |

Appendix Table 3.8 Analysis of variance table for leaf N content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 0.02434 | 0.01217 | 0.96 | |
| Vegetable | 2 | 0.03071 | 0.01535 | 1.21 | 0.319 |
| Micronutrient | 3 | 0.05032 | 0.01677 | 1.32 | 0.294 |
| Vegetable.Micronutrient | 6 | 0.05529 | 0.00922 | 0.72 | 0.635 |
| Residual | 22 | 0.28019 | 0.01274 | | |
| Total | 35 | 0.44086 | | | |

Appendix Table 3.9 Analysis of variance table for leaf P content

| Source of variation | d.f. | s.s. | m.s . | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 0.00224 | 0.00112 | 0.11 | |
| Vegetable | 2 | 0.41129 | 0.20564 | 19.47 | <.001 |
| Micronutrient | 3 | 0.01643 | 0.00548 | 0.52 | 0.674 |
| Vegetable.Micronutrient | 6 | 0.01404 | 0.00234 | 0.22 | 0.966 |
| Residual | 22 | 0.23236 | 0.01056 | | |
| Total | 35 | 0.67636 | | | |

Appendix Table 3.10 Analysis of variance table for leaf S content

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 0.023539 | 0.011769 | 2.88 | |
| Vegetable | 2 | 0.052422 | 0.026211 | 6.40 | 0.006 |
| Micronutrient | 3 | 0.078278 | 0.026093 | 6.37 | 0.003 |
| Vegetable.Micronutrient | 6 | 0.021089 | 0.003515 | 0.86 | 0.540 |
| Residual | 22 | 0.090061 | 0.004094 | | |
| Total | 35 | 0.265389 | | | |

## Appendix 5 Analysis of variance tables for chapter 8

Appendix Table 4.1 Analysis of variance for shoot dry mass

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 11.151 | 5.576 | 2.71 | |
| Basal_fertilizer | 2 | 3089.305 | 1544.653 | 751.22 | <.001 |
| Nitrogen_rate | 3 | 207.618 | 69.206 | 33.66 | <.001 |
| Basal_fertilizer.Nitrogen | 6 | 221.945 | 36.991 | 17.99 | <.001 |
| Residual | 22 | 45.236 | 2.056 | | |
| Total | 35 | 3575.256 | | | |

Appendix Table 4.2. Analysis of variance for plant height

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 15.58 | 7.79 | 0.26 | |
| Basal_fertiliser | 2 | 18476.37 | 9238.19 | 305.58 | <.001 |
| Nitrogen_level | 3 | 94.42 | 31.47 | 1.04 | 0.394 |
| Basal_fertiliser.Nitrogen | 6 | 535.26 | 89.21 | 2.95 | 0.029 |
| Residual | 22 | 665.10 | 30.23 | | |
| Total | 35 | 19786.74 | | | |

Appendix Table 4.3 Analysis of variance for number of branches

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 3.6358 | 1.8179 | 1.87 | |
| Basal_fertiliser | 2 | 718.2469 | 359.1235 | 369.17 | <.001 |
| Nitrogen_level | 3 | 77.1944 | 25.7315 | 26.45 | <.001 |
| Basal_fertiliser.Nitrogen | 6 | 30.6667 | 5.1111 | 5.25 | 0.002 |
| Residual | 22 | 21.4012 | 0.9728 | | |
| Total | 35 | 851.1451 | | | |

## Appendix 6 Analysis of variance tables for chapter 9

Appendix Table 5.1 Analysis of variance table for % germination of Corchorus olitorius at University of Zululand

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 4 | 73.51 | 18.38 | 1.16 | |
| Species | 2 | 7856.09 | 3928.04 | 248.04 | <.001 |
| Heat_treatment | 5 | 33528.22 | 6705.64 | 423.43 | <.001 |
| Species.Heat_treatment | 10 | 19405.24 | 1940.52 | 122.53 | <.001 |
| Residual | 68 | 1076.89 | 15.84 | | |
| Total | 89 | 61939.96 | | | |

Appendix Table 5.2 Analysis of variance table for arc-sine transformed % germination of Corchorus olitorius at University of Zululand

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 4 | 77.22 | 19.30 | 1.27 | |
| Species | 2 | 3746.81 | 1873.40 | 122.98 | <.001 |
| Heat_treatment | 5 | 23653.92 | 4730.78 | 310.55 | <.001 |
| Species.Heat_treatment | 10 | 10566.85 | 1056.69 | 69.37 | <.001 |
| Residual | 68 | 1035.88 | 15.23 | | |
| Total | 89 | 39080.68 | | | |

## Appendix 7 Analysis of variance tables for chapter 10

Appendix Table 6.1 Analysis of variance table for Fresh mass (grams) of Cleome gynandra

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 3.533 | 1.767 | 0.33 | |
| Flowering_state | 1 | 177.075 | 177.075 | 33.08 | <.001 |
| Nitrogen_level | 2 | 263.793 | 131.896 | 24.64 | <.001 |
| Flowering_state.Nitrogen | 2 | 30.627 | 15.314 | 2.86 | 0.104 |
| Residual | 10 | 53.523 | 5.352 | | |
| Total | 17 | 528.552 | | | |

Appendix Table 6.2 Analysis of variance table for dry mass (grams) of Cleome gynandra

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Replication stratum | 2 | 0.7484 | 0.3742 | 1.60 | |
| Flowering_state | 1 | 8.0891 | 8.0891 | 34.69 | <.001 |
| Nitrogen_level | 2 | 8.3282 | 4.1641 | 17.86 | <.001 |
| Flowering_state.Nitrogen | 2 | 1.6060 | 0.8030 | 3.44 | 0.073 |
| Residual | 10 | 2.3318 | 0.2332 | | |
| Total | 17 | 21.1035 | | | |