Developing a research agenda for promoting underutilised, indigenous and traditional crops

Report to the

WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

Over the past two decades, the Water Research Commission (WRC) of South Africa, through its Key Strategic Area (KSA) on Water Utilisation in Agriculture, has championed research on underutilised crops. This was driven by the realisation that the complexity of challenges related to water scarcity, climate variability and change, population growth, and changing lifestyles required innovative solutions and paradigm shifts. In order to propel underutilised crops from the peripheries of subsistence agriculture in niche agro-ecologies to the promise of commercial agriculture there was a need to support robust and comparable scientific research. To this end, the WRC formulated an underutilised crops research strategy that was informed by three themes, namely, (i) drought and heat tolerance of food crops, (ii) water use and nutritional value, and (iii) nutritional water productivity. Under these themes, the WRC has supported the generation of a significant body of information on underutilised crops in South Africa (*cf*. **Appendix 3**). The objective of this WRC directed call was to conduct a state-of-the-art literature review on past, present and ongoing work on underutilised, indigenous and traditional crops and their status, potential, challenges and opportunities along the value chain in South Africa with the objective to develop a draft agenda for future funding on underutilised crops research.

As part of developing the draft strategy, a three phased approach was adopted. Firstly, a diagnosis of challenges, obstacles and opportunities was conducted to aid in the formulation of objectives (*cf*. **Chapter 1**). This also included developing recommendations and a guiding framework for addressing identified challenges and opportunities. Secondly, for successful strategy development, there is always a need to set priorities. The second phase thus included developing a list of priority underutilised crops based on drought and heat stress tolerance and nutrient density. The list of priority underutilised crops and the criteria applied to develop it were consistent with the WRC's current strategy. In addition, this also included outlining coherent actions and activities and identifying key stakeholders and partners (*cf*. **Chapter 2**). Thirdly, the research value chain approach was adopted to outline a draft strategic framework for funding future research, development and innovation (RDI) for underutilised crops in South Africa (*cf*. **Chapter 3**). Consistent with the existing strategy, the draft agenda paid particular attention to drought tolerance and nutritional value of underutilised indigenous crops.

Despite emerging interest on underutilised crops, research on them remains scanty and scattered. Several underutilised crops have been reported to be drought tolerant, adapted to low levels of water use and thus suitable for cultivation in most rural areas. Some underutilised crops would be suitable for promotion during drought periods such as the 2015/16 drought. Existing South African research on drought and heat tolerance and water use of underutilised crops has mainly been funded by the WRC and the Department of Science and Technology (DST). However, despite these efforts, there are still significant gaps on information describing basic aspects of underutilised crops production. These include information on seed systems, crop improvement, agronomy and ecophysiology, post-harvest handling and storage, and agro-processing (*cf*. **Section 1.5.1**). While gaps still exist, significant progress had been made with regards to agronomy and eco-physiology of underutilised crops. In addition, a significant amount of existing literature on underutilised crops focused on particularly one group of crops – traditional vegetable crops. While there is ongoing research on cereal and grain crops (WRC K5/2272//4), there is a need to ensure that future research focusses on all crop categories, i.e. cereals, legumes, vegetable crops, and root and tuber crops. In addition, in order to achieve rapid gains, there is a need to prioritise research on those crops that show the best prospects of success for addressing the poverty-unemployment-inequality nexus. Thus, there is a need to prioritise underutilised crops that are drought and heat stress tolerant as well as nutrient dense.

A total of thirteen (13) underutilised crops were identified as priority underutilised crops, based on their drought and heat tolerance as well as nutritional value (*cf*. **Section 2.3.3**). To ensure diversity going forward, priority underutilised crops were categorised according to cereals, legumes, root and tuber crops, and traditional vegetable crops. It was noted that the list of priority underutilised crops was a draft and should be subjected to further scrutiny by experts on underutilised crops. The draft strategy proposes that priority underutilised crops be promoted as alternatives, especially in marginal production areas where they may have competitive and comparative advantages due to their tolerance to drought and heat stress.

The draft strategy acknowledges that several underutilised crops hold potential for addressing pressing national challenges such as the poverty-unemployment-inequality and water-food-nutrition-health nexus. It proposes that future research, development and innovation for underutilised crops should focus on supporting and developing value chains for the identified priority underutilised crops. This will lead to the development of new value chains and open new opportunities for employment creation for previously disadvantaged communities, women and youths through participatory action research and formulation of priorities. The draft strategy acknowledges the need to integrate scientific and indigenous knowledge as part of a knowledge management strategy. This should also include the development of a database for archiving available information on underutilised crops in South Africa.

Lastly, the success of any strategy also depends, to an extent, on the presence of champions. Similar to how the WRC has been championing underutilised crops research in South Africa, there is a need to identify and promote individual researchers and/or institutions that have demonstrated passion and capacity to drive RDI on underutilised crops in South Africa. In this regard, several researchers and institutions were identified as possible champions based on consistency of publications on underutilised crops (*cf*. **Section 2.3.2**). These should be targeted and supported in future in order to ensure continuity, capacity development and retention of research skills on underutilised crops.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
ARC	Agricultural Research Council
CWR	Crop Wild Relatives
DAFF	Department of Agriculture, Forestry and Fisheries
DST	Department of Science and Technology
IK	Indigenous Knowledge
NARS	National Agricultural Research Stations
NUS	Neglected and Underutilised crop Species
NWP	Nutritional Water Productivity
NDP	National Development Plan
PGR	Plant Genetic Resources
RDI	Research, Development and Innovation
SADC	Southern African Development Community
SANBI	South African National Biodiversity Institute
SDGs	Sustainable Development Goals
UKZN	University of KwaZulu-Natal
UITC	Underutilised Indigenous and Traditional Crops
WRC	Water Research Commission
WUE	Water Use Efficiency
WP	Water Productivity

CHAPTER 1
CURRENT STATE OF UNDERUTILISED CROPS IN SOUTH AFRICA

T. Mabhaudhi, V.G.P. Chimonyo and A.T. Modi

1.1 INTRODUCTION

Climate change predictions suggest that South Africa will experience decreasing rainfall in some areas, increased rainfall variability and frequency of extremes such as drought and floods (Ziervogel et al., 2014) Currently, increasingly low and variable rainfall patterns in South Africa threaten the viability and sustainability of food production in rural areas hence threatening food and nutrition security in poor rural households. The potential of underutilised indigenous crops to contribute under such conditions has been highlighted in several publications (Chivenge et al., 2015; Mabhaudhi et al., 2016a; Mabhaudhi et al., 2016b; Modi & Mabhaudhi, 2013). However, despite reports of their potential and emerging interest on underutilised crops, research on them remains scanty. Some of these underutilised crops would be most suitable for promotion during periods of drought.

Underutilised indigenous crops represent an important component of South Africa's agro–biodiversity with potential to contribute to meaningful socio-economic development and transformation in poor rural areas. Most of these underutilised indigenous crops possess attributes that make them ideal for production under low input agricultural systems and in marginal production areas which typify South Africa's rural landscape. Reports by Modi and Mabhaudhi (2013) showed that several underutilised indigenous crops were drought tolerant, had good heat stress tolerance and were adapted to low levels of water use. These unique attributes suggest that underutilised indigenous crops would be ideal for promotion during periods of drought such as the 2015/16 drought that was experienced across South Africa. However, a paucity of information describing their agronomy, water use and lack of production guidelines have previously been cited as the bottlenecks to their promotion.

Over the years, the Water Research Commission of South Africa has invested in research and development on underutilised crops. These efforts included screening for drought tolerance in several underutilised indigenous crops (Spreeth et al., 2004) describing the agronomy and determining drought tolerance and water use of selected underutilised indigenous crops (Modi and Mabhaudhi, 2013). Currently, there are other on-going projects focussing on determining water of indigenous cereal and legume food crops (WRC, 2014) and determining nutritional water productivity of underutilised crops (WRC, 2014; WRC, 2016). These efforts, coupled with others by the national Department of Science and Technology (DST) in South Africa and through other external partnerships, have led to an increase in the amount of information available on underutilised indigenous crops.

1.1.1 Fitting Underutilised Crops

While the efforts to date are plausible, they have mainly been guided by the realisation that there was potential for underutilised crops and that information needed to be generated on them. As such, past and present research has been focussing on generating information of the range of underutilised crops without focus on particular or specific underutilised crops. In addition, the current research has mainly been at the start up point of the value chain with less focus on the supporting activities of the value chain. This has inadvertently created an incomplete body of literature for underutilised crops and no models for how to transform them from being underutilised to being utilised. There is therefore a need to consolidate on gains already made and the momentum that has been built within the underutilised crops research community and articulate a way forward for underutilised crops in South Africa.

There is a need to articulate a strategy for developing underutilised crops in South Africa with priority given to drought tolerant and nutrient dense crops that can be fitted into the dryland cropping systems typical of rural areas. An initial step to developing a good strategy involves a systematic diagnosis of the challenges, obstacles and opportunities and developing recommendations for dealing with challenges. Therefore, the objective of this review was to assess the current status of underutilised crops in terms of research, their role in cropping systems and current crop choices and to identify their potential contribute to national development agenda, in particular, food and nutrition security as well as employment and wealth creation in poor rural communities. A key focus of the review was aligned to the role that underutilised crops have to play as drought tolerant and nutrient dense crops, especially during drought periods.

1.2 METHODS

A mixed method review approach, which includes combining quantitative and qualitative research or outcomes with process studies was used to compile the review. Emphasis was placed on use of literature from South Africa and this was sometimes compared with international literature so as to assess the gaps in local knowledge relative to international knowledge on NUS. For section 3, articles were identified through searches on Google Scholar databases for the period from 1960 to August 2016. The main search terms used were "traditional", "indigenous", "neglected", "orphan", "new", "future" or "neglected and underutilised crop species". The search did not discriminate by searching within keywords, titles and abstracts but searched for key terms throughout the articles. As such, the search was largely web-based and designed to cover both grey and academic literature. The main advantage of this was that it extended the search beyond articles that would normally be unavailable for the audience outside research. The number of hits was ~5000 and these were screened for relevance to the objectives of the review; ~100 were then cited in the text. For Section 1.4, approaches used were mainly a critical review literature (i.e. qualitative) using the research value chain approach.

1.3 ALIGNING DEFINITIONS

According to Blum (2016), "correct definitions are not just a matter of formality but rather an essential road map for research." Consensus definitions determine success or failure of research and "that lack of consensus of definitions and their proper use in research can undermine attempts to repeat the specific research and its results" (Blum, 2016). These words echo the sentiments expressed by Mabhaudhi et al. (2016b) when they argued that the lack of a consensus definition for underutilised crops was one of the reasons for the limited impact that research has had. They suggested that a starting point to developing a global agenda would the development of a consensus definition for underutilised crops. Currently, there is an array of definitions that have been used, each with different meaning and context, and this has tended to work against underutilised crops. The lack of a clear consensus definition has contributed, in part, to the fragmentation of research outputs and seeming 'lack' of a coherent body of literature on these crops. While this discussion may be global, it also relates to South Africa.

We identified the different names that have been used in the literature for the past 50 years (1960 to 2015). The different terms that were identified included traditional, indigenous, neglected, orphan, new/future crop species (Figure 1.1). The objective of this section is to attempt to align South African definitions currently in use with emerging global trends. In line with the renewed drive to promote production, uptake and utilisation of underutilised indigenous and traditional crops in South Africa and elsewhere, there is a need to align local research focus and outputs with global trends.

Over a 50-year period, results of a literature search showed that the majority of articles published on underutilised crops with reference to South Africa used the term 'traditional crop species' to identify them (Figure 1.1). In this context, traditional crop species referred to crops that were synonymous with a certain geographic location had have great cultural significance. They are traditional in the sense that they have been assimilated into the culture of communities. These crops are also often referred to as 'landraces' with geographic and cultural importance. The definition of traditional crops applied here does not place any emphasis on the crops being indigenous or 'indigenised' but rather places emphasis on the fact that these crops form part of the history and culture of the geographical area and communities concerned. This definition allows for the list of crops to vary from place to place and among different communities.

The word traditional gives the impression that many of the so called underutilised crops only have relevance within certain regions, communities and geographic locations. It also suggests that these crop species may be too primitive to be considered within the global markets and hence unintentionally giving rise to social exclusion. As such, information regarding their husbandry has always been strongly tied to indigenous knowledge systems (Chivenge et al., 2015) which can easily become eroded due to changes in food crop preferences.

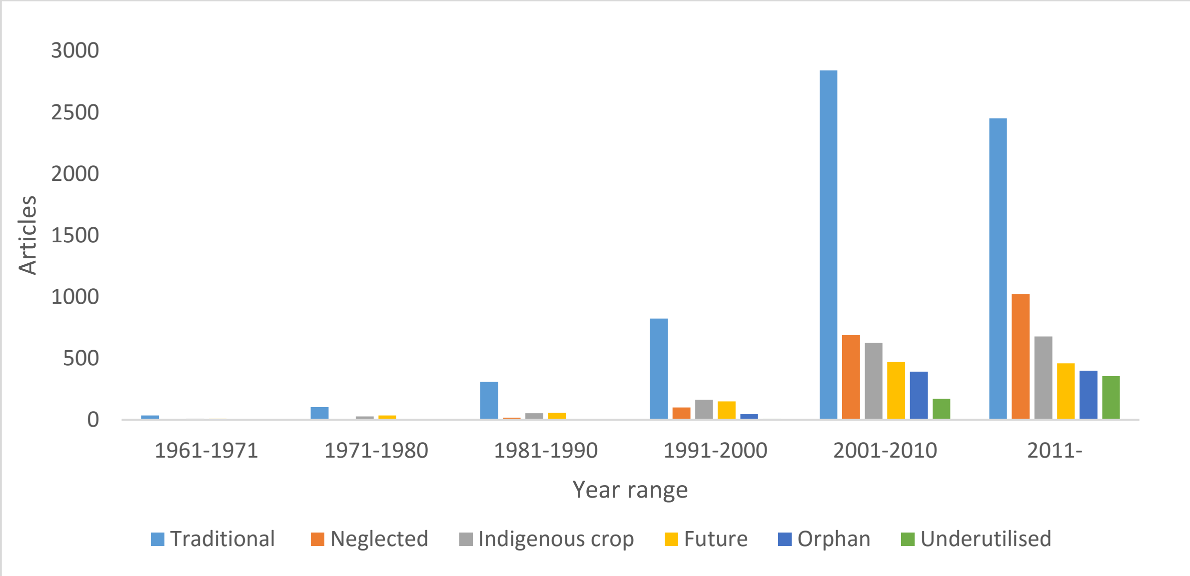

Figure 1.1: Articles across different time periods in reference to South Africa that give reference to the terms Traditional, Neglected, Indigenous, Future, Orphan and Underutilised crop species.

By the early 1980s, it was recognised that the over-simplification of agriculture was contributing to increased risk for global crop production. As such, advocacy for adoption of sustainable farming systems and indigenous knowledge systems increased and with it terms such as "indigenous" and "future" crop species started to emerge in South African literature. These definitions are described below:

- *Indigenous crops*– refers to crop species that have originated from within the geographical area of interest. They are often characterised by limited development relative to their potential. The term 'indigenous' has also often been used to refer to crops that may have originated elsewhere but have undergone extensive domestication locally thus giving rise to local variations i.e. 'naturalised/indigenised crops'. The latter group of crops is also often referred to as traditional crops
- *New or Future crops* – refers to crops that previously did not have significant industrial importance due to low levels of utilisation but that may offer potential to spurn new value chains. It also could be crop species that currently may not be contributing significantly but have the potential to contribute significantly in the future. These crops are not 'new' per se but rather that they offer an alternative to

already commercialised crop species. A lot of the ‘potential’ of new crops is currently based on anecdotal evidence due to limited empirical research. This basket of crops includes indigenous and traditional crops and may have wider geographical applicability than the former and latter terms.

Similar to “traditional”, the use of the term “indigenous” crop species suggested relevance of the crops at a community or geographic level. Communities with limited crop diversity would be at a disadvantage considering that stability and sustainability of agriculture has been linked to high crop diversity. The emergence of ‘future’ crops concurrently with indigenous crops suggests that the potential of these crop species had been recognised but these crop species could not be placed within existing cropping systems due to limited information and the strong reliance on major crop species. The term ‘indigenous’ could have restricted a wider applicability of these crop species while the term ‘future’ might have affected the temporal applicability.

Before the turn of the century researchers realised that much of the information regarding many of the underutilised crop species was largely anecdotal. As a result, the use of terms such as ‘neglected’ and ‘orphan’ began appearing in the literature. This was an acknowledgement of the fact that research had not fully advanced the development of these crop species. The two terms are described below:

- *Neglected crops* – are those that could have significant potential within geographic niche areas but have been marginalisation as a result of low social prestige, laborious methods of preparing them and low economic returns in farming systems.

- *Orphan crops* – those crops which are typically not traded internationally but can play an important role in regional food security. Similarly, many of these crops have received little attention from crop breeders or other research institutions that can improve their production potential.

There are strong parallels between ‘neglected’ and ‘orphan’ crop species with respect to their use. They were once part of traditional cropping systems but have since been overtaken by better performing exotic crop species. Most of these crop species are currently not housed in any research agenda and are inadequately researched and geographically isolated hence they are ‘neglected’ or ‘orphan’ crops.

By the turn of the century, it was widely recognised that, although such crop species had much potential, they still occupied low levels of utilisation relative to their perceived potential and to major crop species; this led to the emergence of the term ‘underutilised’. However, the use of the term ‘underutilised’ often does not give reference to *where, when* and by *whom* (Padulosi et al., 2002). There are also issues to do with social stigma were some these crops may be regarded as “poor men’s crops” or associated with “backward practices” lack of popularity among local communities. In South Africa, the term ‘underutilised indigenous and traditional crops’. These different terms are also discussed below:

- *Underutilised crops* – refers to crops which may have considerable potential for use but this potential has barely been utilised. Often these crop species are globally distributed and have vast potential but their utilisation is currently confined to ecological niche areas. Underutilised crops are not limited to indigenous, indigenised or traditional crops and often varies from place to place and among different communities.

- *Underutilised indigenous and traditional crops* – often termed as last resort food crops, these that are also grown primarily in their centres of origin or centres of diversity by traditional farmers, where they are rarely consumed and at times unknown or unfamiliar to many of the younger generations in their locality. As such they face genetic erosion due to loss of indigenous knowledge that accounted for their use and conservation.

- Underutilised indigenous and traditional crops can be defined as crops that have either originated in specific niche environment or those that have become “indigenised” over many years of cultivation and selection. These are crops that have not been previously classified as major crops, have previously been under-researched, currently occupy low levels of utilisation and are mainly confined to small-scale farming areas (Azam-Ali, 2010). Historically, such crops have played an important role in ensuring community and household food security through providing healthy

The concept of neglected and underutilised crop species has been used over the last 20 years to refer to plant species with significant potential as food and industrial crops but are marginalized, if not entirely side-lined, by researchers, breeders, policy makers, producers and traders (Ebert, 2014). As a result, they have poorly developed and understood value chains. They are non-commodity crops and belong to a large, biodiverse group of domesticated, semi-domesticated or wild species and in most instances, are locally adapted (Padulosi et al., 2013). They tend to be grown primarily in their centres of origin or centres of diversity by traditional farmers, where they are still important for the subsistence of local communities. As such, they are managed within traditional systems, use informal seed sources and involve a strong gender element (Dansi et al., 2012). Their processing is often described as laborious, with primitive value chains, while products are marketed locally with limited involvement of large enterprises (Padulosi et al., 2013). Having long been neglected by mainstream agriculture for a variety of agronomic, genetic, economic, social and cultural reasons, today these crops are receiving increasing recognition because of their potential role in mitigating risk in agricultural production systems and promoting food security (Padulosi & Hoeschle-Zeledon, 2004).

Overall, and by definition, the term NUS considers all the main aspects of the terms traditional, indigenous, neglected, orphan, new/future crop species. It allows crops to have social, geographic and economic relevance. While the global trend in publications appears to be gravitating towards the adoption of the term 'NUS', South African literature seemed to remain scattered among different terms. Of the publications considered for this exercise (i.e. 1960–2016), less than 15 peer-reviewed articles that were published for South Africa used the term NUS. Considering the various local research outputs, the term NUS is applicable for use to define the range of underutilised crops and terminology used to describe them in South Africa. There is a need to align to South African literature with emerging global trends. This will contribute to the increased visibility of local research outputs on the global stage as well as allow for archiving and consolidation of such outputs. Part of the solution to promoting underutilised crops lies in getting all stakeholders to speak the same language – adopting a consensus definition would be an initial step towards achieving this.

1.4 SMALLHOLDER AGRICULTURE IN SOUTH AFRICA

The agricultural sector is characterised by a dual economy, with a well-developed commercial agricultural sector and a less-developed, dynamic smallholder agricultural sector (Wenhold et al., 2007). As of 2012, the commercial agricultural sector comprised about 40 000 farming units and these covered a production area of 82 million ha (Hoffmann et al., 2014). In contrast, the smallholder sector comprised more than 1.4 million small family farms that occupied less than 14 million ha. The observed imbalance of land distributed is historic and dates back to South Africa's colonial past (Knight et al., 2014). Communal agricultural lands, mostly located within the former homelands, are characterised by degraded soils due to over–population, over–grazing, exhaustive farming systems and poor soil and water management practices

(Mandiringana et al., 2005). As a result, agricultural productivity has been observed to be low and unsustainable in these areas (Giller et al., 2009).

Nevertheless, agriculture continues to play an important role in rural livelihoods and has been prioritised by government as a means to reduce poverty and food and nutrition insecurity (Government of South Africa, 2015; National Planning Commission, 2013). Smallholder farmers remain under–developed with regards to their potential. They face numerous socio-economic and bio-physical constraints mostly associated with low access to credit, poor soil quality, low water availability and poor access to seed of improved crop varieties. According to national statistical database STATSSA, it is in these areas where there is the highest prevalence of poverty and food and nutrition insecurity (STATSSA, 2016). It is in this context that neglected and underutilised crops hold significant prospects as they offer meaningful opportunities for sustainable development solutions under low input agricultural systems (Mabhaudhi et al., 2016b). Therefore, the focus of this review is on smallholder farmers and identifying the role that underutilised crops in rural landscapes.

This section provides an overview of land suitability of South Africa by exploring existing farming and cropping systems as well as crop diversity within these systems. We also critic the suitability of existing cropping systems and crop choices with regards to socio-economic and bio-physical constraints within marginalised rural landscapes. The objective is to highlight the role and status of NUS within South Africa’s farming and cropping systems with the aim of strengthening the justifications for their inclusion in the crop choice. For the purpose of this review, farming systems are understood to represent a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Nested within these farming systems are cropping systems which are defined as a community of plants which are managed by a farm unit to achieve various human goals.

1.4.1 Overview of Land Suitability

South Africa’s land suitability for agriculture was determined using the land capacity classification systems which groups land using physical properties (soil, terrain and climate) on the basis of their capability to produce common cultivated commercial and pasture crops without deteriorating over a long period of time. Land capability provides a framework that combines soil, terrain and climate factors to assess the most intensive long-term use of land for rain-fed agriculture and at the same time indicates the permanent limitations associated with the different land-use classes. For South Africa, all eight land (Figure 1.2) classes have been observed and only 2% of the land cover constitutes high potential areas (Class 1 and 2) and is highly suitable for rainfed agriculture (DAFF, 2011). The majority of the land (70.5%) has been classified (Class 5 – 8) as unsuitable for rainfed crop production due to the combination of poor rainfall and poor soils. According to Paterson (2015), many of the former homelands are found between Class 4 and 7 indicating that these farmers have a low, if not non-existing, agricultural potential to produce under rainfed conditions.

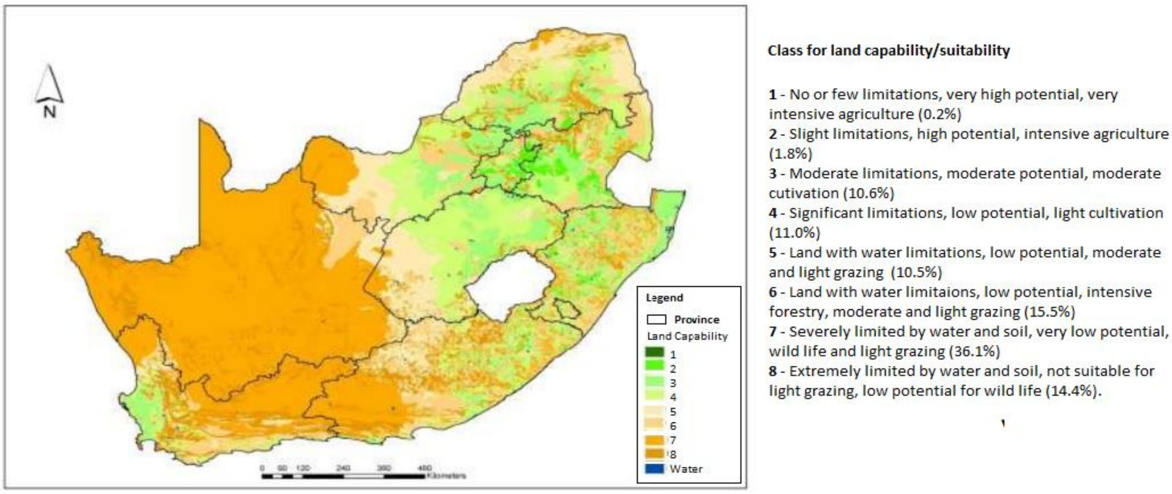

Figure 1.2: Land capability map for South Africa (Source: Schoeman et al., 2002))

While land capability classification system has been used widely for South Africa, it is limited to and for major crop species and does not consider NUS. This has probably contributed to the promotion of a few major crops while most NUS have been relegated to their current status of low utilisation. Areas were NUS are extensively cultivated have been observed to be marginal and often considered unsuitable for rainfed agriculture. This is despite the fact that several NUS continue to exist in these niche agro-ecologies which are deemed unsuitable for major crops. Modi and Mabhaudhi (2013) hypothesised that the fact that NUS continue to survive in these harsh agro-ecologies lends credibility to the argument that they possess tolerance to several abiotic stresses such as drought and heat stress. Their continued existence, albeit with little support, also highlights the limitations of the current land capability classification in acknowledging the natural agro-diversity of marginal agricultural lands. In order to fully exploit the potential of existing agricultural lands under smallholder farming systems, there is need for a paradigm shift. Incorporating aspects of agro-ecology into the land capability classification system could broaden the scope of crops currently considered through a change in what is considered as “arable land” to “land arable for”. Currently, land suitability refers to “arable land” and this encompasses land that can sustain crop production activities without over reliance of external resources. On the other hand, a shift to “land arable for” places emphasis on crops suitable for a particular agro-ecological zone and its given resources. As such land can be subdivided further according to the range of adaptable crop species; that is, appraising crop species for a given landscape. Thus, increasing what we may consider as arable land and directly increasing the recognition of NUS in smallholder farming systems, especially those operating in marginal environments.

While NUS are generally considered as important by smallholder communities, it remains difficult to identify their functional role within already existing farming and cropping systems. There have been attempts to establish the role of NUS at a regional level for the Southern African Development Community (Mabhaudhi et al., n.d.). The SADC report showed that NUS played a multipurpose role within most rural communities. Their multipurpose nature also explained their continued preservation by such communities (Mabhaudhi et al., n.d.). For South Africa, while there has been emerging interest on NUS, there has been limited attention on identifying their role within farming and cropping systems. This information is important as an initial step to establishing a baseline for promoting NUS.

1.4.2 Overview of Farming and Cropping Systems in South Africa

South Africa’s farming and cropping systems are mainly determined by the agro-ecological zone in which they exist. Based on rainfall and temperature averages, the country can be sub–divided into six agro-ecological zones (AEZs), namely desert, arid, semi-arid, sub-humid, humid and super humid. The amount of rainfall decreases from east to west with super-humid region, which constitutes 2.8% of the country being situated in the east and arid and desert which constitutes 47.4% in the west. (Figure 1.3). The interior is made up of both semi-arid and sub-humid AEZ and based on historical land distribution this is where majority of smallholder farmers are located. As such, the discussion on farming and cropping systems will focus on the suitability of farming and cropping systems for smallholder farmers within the semi-arid and sub-humid AEZ.

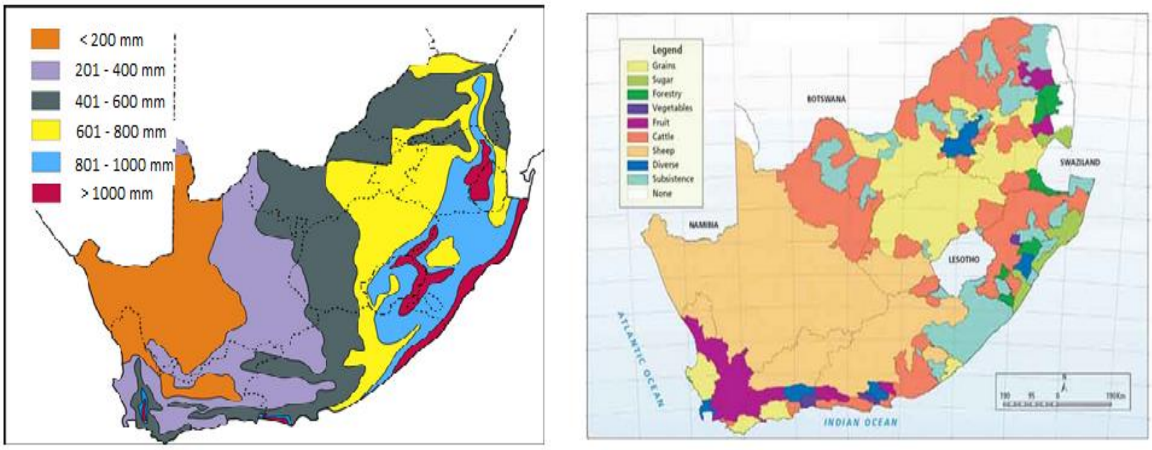

Figure 1.3: Rainfall distribution and farming systems across South Africa (Source: http://awsassets.wwf.org.za/downloads/facts_brochure_mockup_04_b.pdf).

The general characteristics of many smallholder farmers in South Africa is that they are resource constrained with poorly developed enterprises. Their main farming systems are agro-pastoral (Table 1.1), regardless of the AEZ, as livestock constitute an important cultural role (Mapiye et al., 2009; Musemwa et al., 2008; Nethononda et al., 2014; Waha et al., 2013). The intensity of agro-pastoral organisation differs with AEZ and is influenced, primarily, by rainfall availability. In the semi-arid regions of the Eastern Cape Province, more than 90% of smallholder farmers have been observed to own a variety of livestock, including cattle, horses, donkeys, goats, pigs, sheep, chickens and turkeys. Less than 50% of smallholder farmers participated in field crop production (Mapiye et al., 2009; Musemwa et al., 2008). This is consistent with the land capability classification that placed much of this areas under class 4 – 6; suitable for pastoral activities and less suitable for rainfed agriculture. On the other hand, in the sub-humid area of the same province, livestock diversity was smaller and most of the smallholder farmers participated in field crop production activities (Chimonyo, 2012).

Regardless of agroecology, maize is the dominant crop produced and this is linked with its status as a staple food crop (Gilimani, 2005). As such, mixed maize and maize systems (Table 1.1) are the dominant types of cropping systems (Bennie & Hensley, 2001; Biazin et al., 2012; Fanadzo et al., 2009; Mathews et al., 2001; Silwana, 2000). Within these cropping systems, food crops such as beans (*Phaseolus vulgaris*), sweet potato (*Ipomoea batatas*), pumpkin (*Cucurbita pepo*) and butternut (*Cucurbita moschata*) are also produced. However, their inclusion into the main cropping systems can easily be forgone due to production risks such as drought. In Limpopo, KwaZulu-Natal and Mpumalanga, smallholder farmers grow sorghum and it is an important cereal crop with multipurpose functions. Other major field crops such as potatoes, sweet potatoes, dry beans, cabbage and spinach play a vital role in the provision of food security within smallholder farming communities (Motsa et al., 2015). As previously alluded to, many of the agricultural landscapes are modelled on commercial production systems and the productivity of maize and other food crops are low given the erratic and low rainfall, frequent droughts and poor soil fertility (Ebert, 2014; Orsini et al., 2013; Rezig et al., 2010; Rogerson, 2003; Van Duivenbooden et al., 2000). It could be that crop choices, that is crop types and/or species, may not be suited for the agro-ecology. Therefore, the crop choice should focus on including crops that are drought tolerant and adapted to low input agricultural systems. In this regard, certain NUS which are drought tolerant and nutrient dense have played a small but significant role within smallholder communities.

Table 1.1: Description of agro-ecologies and associated farming and cropping systems where many of the smallholder farmers are found in South Africa.

Agro-ecological classification	**Biome**	**Farming systems**	**Cropping system**	**Observed NUS**
Sub-humid	Grassland savannah/ savannah	Agro-pastoral and Mixed maize	Mixed maize	Sorghum, millets, African eggplant (*Solanum macrocarpon*, *S. aethiopicus* and *S. anguivi*), vegetable and grain cowpea, wild mustard (*Brassica carinata*) and jute mallow (*Corchorus olitorius*) Chinese cabbage (*Brassica rapa* L. subsp. Chinensis), pumpkin (*Cucurbita maxima*), various *Cucurbita spp.*, bitter watermelon (*Citrullus lanatus* (Thunberg) Matsum. subsp. Lanatus), spider plant (*Cleome gynandra* L.) cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), grain cowpea, bambara groundnut (*Vigna subterranea*) and taro (*Colocasia esculenta*)
Semi-arid	Nama karoo/ savannah	Agro-pastoral and Mixed maize	Maize, sorghum and millets	Sorghum, millets, African eggplant, vegetable and grain cowpea, wild mustard, jute mallow, Chinese cabbage, various *Cucurbita spp*., bitter watermelon, spider plant, sweet potato, bambara groundnut, Fat hen (*Chenopodium album*), Spindle-pod (*Cleome monophylla*), Jelly melon (*Cucumis metuliferus*), Devil's thorn (*Emex australis*), Gallant soldier (*Galinsoga parviflora*), Yellow justicia (*Justicia flava*), Stars talk (*Oxygonum sinuatum*), Sticky gooseberry (*Physalis viscose*), Purslane (*Portulac oleracea*), Coffee senna (*Senna occidentalis*) and Black nightshade (*Solanum nodiflorum*) and Giant bell flower (*Wahlenbergia undulata*)

Several NUS have been identified to be consumed across smallholder communities and these range from cereal, legume, root and tuber, and leafy vegetables; the latter was the main form of NUS across AEZs. The popularity of leafy vegetables, also referred to as African Leafy Vegetables (ALV), was attributed to their short growing season, high nutrient content, low agronomic requirements, drought tolerance, unique and acquired taste and their abundance in the wild (Faber et al., 2010; Kwenin et al., 2011; Oelofse & Averbeke, 2012; Schönfeldt & Pretorius, 2011). Across smallholder communities, more than 45 NUS have been documented to be in use (Jaarsveld et al., 2014; Modi and Mabhaudhi, 2013; Oelofse and Averbeke, 2012; van Rensburg et al., 2007; Wenhold et al., 2007). Notably, the diversity of NUS was higher within the semi-arid region (Table 1.1) where they are collected and/or produced, and traded within informal markets. The potential of NUS under water scarcity in semi-arid areas has previously been established by Chivenge et al. (2015). Several of these NUS are known to be drought tolerant and nutrient dense and thus suited to addressing food and nutrition issues in water scarce environments (Chivenge et al., 2015). Promoting NUS within water scarce areas offers opportunities not just to address food and nutrition security (Mabhaudhi et al., 2016a) but to create autonomous pathways out of poverty (Mabhaudhi et al., 2016b) However, despite the emerging body of evidence indicating their potential in water scarce environments and opportunities for sustainable development, there still lacks a coherent policy framework to support their expansion (Mabhaudhi et al., n.d.) (Mabhaudhi et al., undated).

By definition, most NUS are tolerant to several environmental stresses and thus should be promoted as part of the crop choice in marginal agricultural production areas. Their vast genetic pool presents an important sub-set of agro-biodiversity; therefore, supporting landscape diversity in marginal cropping systems (Mabhaudhi et al., 2016b) The promotion of NUS in smallholder communities should not seek to substitute current major crops, rather it should focus on diversifying current cropping systems. This will also contribute to cropping systems diversity, resilience and improved dietary diversity (Mabhaudhi et al., 2016a) Currently, many of the cropping systems have a narrow genetic base, relying on a few major crop species. This is consistent with global agricultural landscapes that are characterised by low agro-biodiversity (Mace et al., 2012) whereby only five crops (maize, wheat, rice, potato and sorghum) account for more than 60% of daily calorific intake. This global agricultural context also mirrors that of South Africa where major crops continue to dominate and be promoted even in areas where they may not be suitable. The lack of diversity also leads to related challenges such as low system resilience and poor nutrition, especially in rural areas where they cannot afford to compliment these major crops with purchased vegetables.

The lack of diversity has resulted in an increase in susceptibility of cropping systems to risk from production constraints (Lithourgidis et al., 2011). In addition, it has reduced the capacity of agriculture to provide food and nutrition security, and support rural livelihoods (Hirel et al., 2011). High agro-biodiversity can result in an improvement of ecological services and function; thus improving resilience of the system (Altieri, 1999). There is also a strong relationship between high agro-biodiversity and food and nutrition security through the increase in food choices, food availability and access (Galluzzi et al., 2010; Munzara, 2007). Therefore, increased agro-biodiversity through the promotion of NUS can improve general livelihood of smallholder communities.

The available literature shows that many smallholder farmers are acquainted with NUS and collect, cultivate and consume them. However, their role seems to be secondary to that of major crops and hence they remain underutilised relative to their potential in these agro-ecologies. The majority of the NUS are leafy vegetables, and these are mostly collected from the wild (Table 1.1). The role of NUS in the food consumption patterns in South African households is highly variable and depends on factors such as poverty status, degree of urbanisation, distance to fresh produce markets and time of year (Faber et al., 2010). It could be argued that consumption of NUS has always been a livelihood strategy by smallholder farmers located in marginal areas. It can be observed that the diversity of NUS increases as the AEZ becomes less conducive for rainfed agriculture. There is strong evidence that several NUS are drought tolerant and also nutrient dense. This is important for South Africa which faces increasing water scarcity as well as food and nutrition insecurity. The role of NUS as part of drought mitigation strategies under rainfed conditions should be explored further. This will entail developing land suitability maps as well as production guidelines for drought tolerant and nutrient dense NUS that can be used to promote them in rural areas. Furthermore, value chains for such drought tolerant and nutrient dense NUS should be unlocked as this will create added value and incentive for their production.

1.5 STATUS OF UNDERUTILISED CROPS IN SOUTH AFRICA

South Africa's (SA) population is expected to reach 65.5 million by 2050 (STATSSA, 2016), which is 10 million more people than the current population. It is projected that the proportion of the population suffering from chronic hunger and over- and under-nutrition owing to food insecurity will increase. In response to the growing demand for nutritious food, agriculture in SA, and elsewhere, will have to increase by more than 50% to sustainably reduce incidences of household food insecurity (Rost et al., 2009). Strategies that have been suggested for increasing agricultural production include (i) expanding area under cultivation, (ii) breeding for new high yielding varieties, and (iii) improved resource efficiency. While South Africa may have land that is currently underutilised, most of this land is located in the marginal production areas. Also, agriculture in South Africa is mostly limited by water availability and hence the focus on resource use efficiency has primarily targeted improving water use efficiency. There remains a possible fourth option that could be considered which also has potential to contribute to the three points mentioned above. Neglected and underutilised crop species (NUS) have the potential to (i) expand land under cultivation, (ii) they have been hailed as a rich sources of germplasm for future crop improvement, and (iii) confer resource use efficiency (land and water), especially under rainfed agriculture and during periods of drought. As such focus has increased in promoting the production and use of NUS within smallholder farming systems.

Despite constituting a small share of agricultural production, NUS have the potential to improve agricultural productivity, food and nutrition security and general livelihood in these farming systems. Research has shown that many NUS are tolerant to abiotic constraints such as water and nutrient stress (Chivenge et al., 2015; Jaarsveld et al., 2014; Oelofse and Averbeke, 2012). Their agro-ecological distribution within South Africa shows that they are highly adapted to areas where smallholder farmers are located (Faber et al., 2010). Despite these advantages, the production of NUS remains low with regards to land area under cultivation, quantities produced and quantitative research outputs. Mayes et al. (2012) highlighted that there was insufficient quantitative information regarding their nutritive traits, agronomy, processing and marketing in comparison with major crop species often grown within these communities. This analysis mirrors the South African context as well. As such, it remains a challenge to quantify the benefits of investing in NUS and promoting them as a livelihood strategy.

The fact that these crops remain underutilised creates an opportunity for the development of new value chains in support of rural agricultural development and food security. There is need to assess the current status of NUS with regards to what has been done in terms of research and development so as to articulate and present a sustainable strategy for their promotion within marginal farming systems. In the subsequent sections, we assess the status of NUS using the research value chains i.e. breeding/crop improvement – production – agro-processing – marketing. The gaps within the research value chain of NUS will be highlighted and possible strategies to overcome these gaps suggested.

1.5.1 Underutilised Crops Value Chains

Any agricultural product needs to pass through a number of stages from the farmers' fields until it reaches the end consumer. There is a variety of participants and activities that account for this movement from farmers' fields to the end user. In-between the producer and the consumer there are a variety of primary and supportive activities that are often done to add value (Fig. 1). Primary activities are product and market related while support activities are those that are related to infrastructure, technology, research and development, and human resources. The cluster and sequence of activities in the production up to the marketing of a product is what have been referred to as "value chain" (Figure 1.4). By definition a value chain refers to the "full range of activities which are required to bring a product or service from conception, through the different phases of production delivery to final consumers, and final disposal after use" (Tran et al., 2013). The value chain approach has often been applied for the economic development of a variety of industrial products and has since become an accepted approach for developing and promoting emerging technologies across different sectors. By analysing the downstream and upstream information along a chain, the value of a product, in this case NUS, can be clearly recognised and enhanced in order to maximise value derived. In addition, it will be easier to identify limiting factors to their production, utilisation and marketing.

In the context of rural agricultural development, value-chain approaches have since become a popular strategy to encourage greater participation in national and international markets. Such a strategy has also been proposed for the promotion of NUS (Padulosi et al., 2002); however, little has been done to develop sustainable value chains. As it is, value chains of NUS have been described as being immature with few activities and actors, in between the producers and the end users, adding value. To ensure successful upscaling up of NUS as a food and commodity crop there is need to identify who the actors are, how do they get involved and what are the support structures that allow for their continued involvement. Figure 1 suggests a basic food value chain outlining the “who”, “when” and “how” considerations that can be used to guide upscaling NUS value chain (Figure 1.4). At the heart of food value chain are support activities that play a pivotal role in identifying and enhancing “value” that is to be added, thus creating an incentive for the involvement of a broader spectrum of actors within the value chain. This set of activities have been coined “research value chain”. As it is, the lack of an explicit focus on the supportive role of research and development may partly explain the slow progress in the development of NUS value chains. The need for research and development is particularly true since much information remains in indigenous knowledge systems and/or is currently anecdotal. A clear and targeted research and development agenda could unlock the potential of NUS. The targeting should be focussed on unlocking and supporting points in the value chain. This can be done by employing the same techniques used in the development of major crops such as biotechnology, crop genetics and breeding, agronomy and agro-processing. This approach has led to the dominance of current major crops whose value chains are supported by a strong and focussed research and development.

1.5.1.1 Biotechnology, crop genetics and breeding

Plant genetic resources (PGR) for food and agriculture play an ever increasing role in ensuring food security and economic development under marginal farming systems. Resilient and sustainable farming systems have been observed to be rich in PGR; high agro-biodiversity. As an integral component of agro-biodiversity, NUS represent an important gene pool that could be used to (a) broaden the current gene pool, (b) future breeding and crop improvement, and (c) expand agriculture into marginal areas characterised by water and nutrient stress. Current breeding efforts are now shifting to identifying crop wild relatives, which are mostly NUS, as sources of germplasm for new breeding programmes. This shift confirms reports that NUS can serve as a primary source of beneficial traits for major crop species (Hirakawa et al., 2014; Holme et al., 2013; Juma, 1989; License, 2016; Prado et al., 2014; Vincent et al., 2013). However, the potential of NUS as a PGR is currently untapped as they are poorly represented in national gene bank collections and do not feature on most research agenda. Therefore, a starting point could be to collect the range of local NUS for South Africa and to characterise them as a source of germplasm. This would allow for breeders to easily access the material and incorporate it in their breeding programmes.

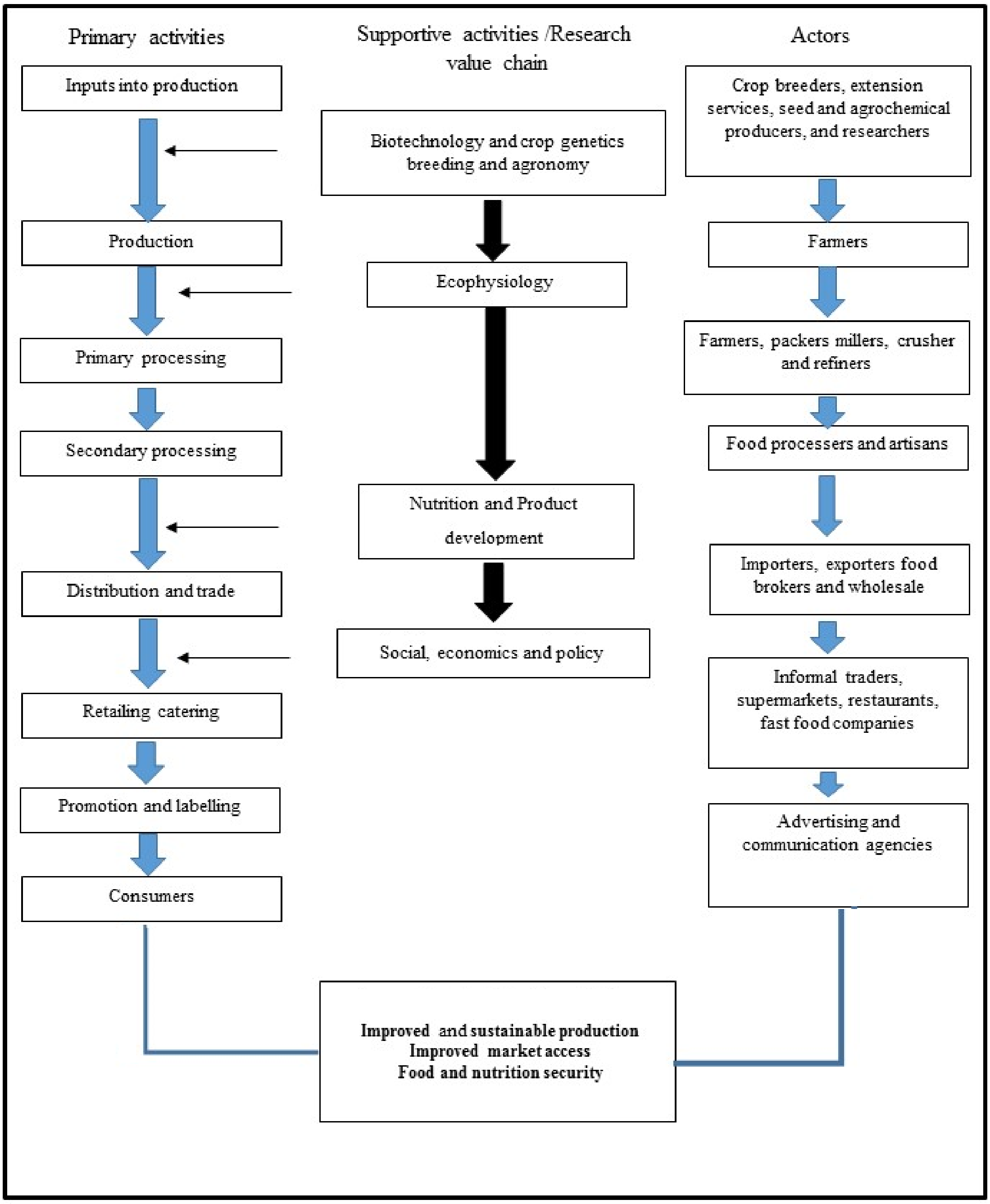

Figure 1.4: Value chain of neglected and underutilised crops indicating primary and support activities, and actors involved during the primary activities.

Considering the need for an immediate intervention with regards to increasing agro-biodiversity, NUS form a significant source of accessible PGR due to their intra- and inter-genetic abundance which can be found across different geographic scales. In South Africa, genetic diversity of NUS remains anecdotal although the country is considered as a “NUS hotspot” (Gaisberger et al., 2016). This is in line with the countries status as megadiverse. Due to the poor documentation of genetic diversity of NUS in the country, it is not clear how much is available and how much has already been lost. A possible reduction of genetic diversity of NUS may inhibit natural evolution and adaptation of crop species (Nyadanu et al., 2015), reduces options for breeding improved cultivars and reducing the resilience of agro-ecosystems and their ability to adapt to stress. There is need to assess the current genetic diversity for NUS for the purpose of their conservation, development and exploitation. Overall and in South Africa, South African Nation Biodiversity Institute (SANBI) has a mandate to collect and conserve crop wild relatives. It also recognises that NUS constitute ‘within-species’ diversity and provide resilience and local adaptation in traditional farming system. As such work has begun on the inventory of NUS. Such work will permit the construction of a dataset that will also serve to identify gaps in gene banks collections with regard to NUS.

While NUS possess several attributes that could drive rural agricultural development, the lack of information creates a disincentive for their investment and entry into formal market systems. According to Dawson (2006), the genetic variations within NUS exhibit partially defined semi- or incipient domestication with superficial characterisation owing to the degree of intra-species heterogeneity. As such, the diversity of benefits provided by NUS often accompany equally diverse shortcomings that often influence their participation in mainstream agriculture.

Biotechnology tools, together with conventional crop genetics and breeding activities, have been employed for the rapid genetic improvement of major food crops and can be used for underutilised crops. The term biotechnology encompasses a range of activities related to DNA, molecular biology and plant reproductive and these include (i) tissue culture and micro-propagation, (ii) characterising genetic diversity, (ii) genetic mapping, marker assisted selection and genomics (iv) genetic modification. In South Africa, the national Bio-economy Strategy’s (DST, 2013) objective for agriculture is to strengthen agricultural biosciences innovation to ensure food security, enhance nutrition and improve health, expand and intensify sustainable agricultural production and processing. Within the strategy, it is recognised that unlocking the value of indigenous crops, coupled with consumer demand for “natural” products, presents opportunities for South Africa to capitalise on its biodiversity and capture niche markets (DST, 2013). There is a need to deploy biotechnology techniques for NUS. This would assist in the development of improved varieties for NUS within shorter time frames relative to conventional breeding. The use of biotechnology could explicitly focus on identifying genetic traits responsible for abiotic stress tolerance in most NUS.

1.5.1.2 Agronomy consideration for the production on NUS

Although NUS are generally considered adaptable to marginal lands a major factor affecting their uptake by smallholder farmers is the limited knowledge regarding their production. For instance, several authors have pointed out issues of seed dormancy, poor seed and seedling establishment, low yield and low storage capacity, susceptibility to pests and diseases and the presence of anti-nutritional compounds (Abdelgadir et al., 2012; Adoukonou-Sagbadja et al., 2007; Chweya & Mnzaya, 1997; Eberhart & Russell, 1966; Mkandawire, 2007; Siddhuraju & Becker, 2000; Vadivel & Janardhanan, 2001); these shortcomings have also been observed in South Africa. Although cultivating low input crops like NUS in marginal lands presents huge advantages, parallel disadvantages may have elevated the promotion of major crop species within smallholder farming systems. For example, Mabhaudhi et al. (2013) argued that the poor establishment of bambara groundnut may partly explain why farmers have moved away from cultivating it. To exploit the full potential of NUS, and promote their adoption into existing cropping systems, aspects of crop and soil management strategies need to be formulated.

Generating information regarding plant densities, fertiliser application rates, planting dates, water requirements, weeding, pest and disease control, and harvest techniques is important for upscaling the production of NUS within smallholder farming systems. This is especially important considering that the efficient use of limited resources such as water can be enhanced through optimum agronomic practises. Combining optimum agronomic practices with improved varieties generated from breeding and biotechnology could help farmers to realise significant increases in yield of NUS. In South Africa, there has been some progress made on assessing agronomic practices and developing best practice recommendations for production of NUS, especially leaf vegetables (Manyelo et al., 2013; van Averbeke, 2002; van Rensburg et al., 2007). For instance, research into African leaf vegetable has covered many aspects of their agronomy and agro-processing. While efforts are being made for cereal, legume and root and tuber, very limited information remains available. A synergy of crop and soil management practices is required to increase yield potential of NUS, especially if they are to be a source of food and nutrition security for smallholder farmers residing in sub-optimum environments.

Therefore, further research is required on the various agronomic aspects of NUS is South Africa.

1.5.1.3The ecophysiology of NUS

The environment in which smallholder farmers reside is characterised as low potential for rainfed agriculture although many rely on rainfed cropping systems for food and nutrition security. In these areas, climate change and variability is worsening the agricultural outlook due to increased incidences of drought and floods. The 2015/16 drought affected many smallholder farmers as they had no access to water for irrigation nor knowledge of rainwater harvesting and conservation techniques. The lack of diversity and drought tolerant crops within their cropping system led to a collapse of the system and exposed families to the risk of hunger. This highlighted that farmers in these areas still lack the necessary skills, financial support and infrastructure to adapt to and mitigate the effects of extreme climate events. It also highlighted the fact that current cropping systems and crop choice may not be suitable for smallholder farming systems and agro-ecologies in which they reside. As such, the promotion of NUS, which have been shown to be highly adaptable to harsh environment, can aid in improving system resilience within these systems.

The productivity of food crops depends on the ability to adapt to environmental and climatic uncertainty. Growing crops that can modify their morphological, anatomical, and physiological as well as biochemical characteristics can contribute to adaptation to such harsh environments. While most NUS have been praised for their ability to grow well under resource limitations like water, and are resilient to climate extremes, there is insufficient empirical and comparable data to support these claims (Mabhaudhi et al., 2016b), especially within the South African context. As such there is need to quantify to what extent NUS are tolerant to harsh conditions such as drought and heat stress; this can be done through evaluating their ecophysiology.

Ecophysiology is the relationship existing between living beings and their physical and biotic environment. It is also interpreted as morphological, anatomical, and physiological as well as biochemical adaptations that ensure the continued survival of a species in a given environment. Several studies in South Africa have alluded to the advantages observed in NUS grown under resource limitations to be related to good ecophysiological responses (Modi and Mabhaudhi, 2013). For instance, Mabhaudhi et al. (2013) stated that stable yields observed in bambara groundnut grown in different water regimes were associated with reduction in canopy size and maintenance of high stomatal conductance. Cowpea was observed to shed leaves and assume a state of growth arrest under prolonged low water availability and resume when soil water availability improves (TerAvest et al., 2015). There is evidence from studies done in South Africa that certain NUS are indeed drought tolerant. The only limitation, perhaps, may be that work done so far has not focused on particular NUS. Rather, it has looked at range of NUS. Whilst this may be plausible with regards to building a body of knowledge on NUS, there is a need to identify certain priority crops that can be focussed on. This will allow for exemplar NUS to be identified, studied and taken through the entire value chain. Success stories for a few NUS may have the impact of shifting attention to NUS.

1.5.1.4 Nutrition and product development

While South Africa may be food secure as a country, large numbers of households remain food insecure (Muzigaba et al., 2016). Food security exists when every person has access to sufficient food to sustain a healthy and productive life, where malnutrition is absent, and where food originates from efficient, effective, equitable and low-cost food systems that are compatible with sustainable use of natural resources (McLachlan, 2011). To date, observed levels of malnutrition have been associated with limited food diversity observed with rural communities. Within smallholder farming communities, diets are dominated by starch–based foods and lack adequate amounts of protein, vitamins and other mineral nutrients. This has been associated with limited food sources and choices (Faber and Wenhold, 2009). Kennedy et al. (2007) stated that dietary diversity is an integral component of a quality diet; both diversity and quality are key to achieving food and nutritional security. As a way of improving household food and nutrition security for smallholder farmers, NUS has been identified as a sustainable and viable means.

The nutritional value of a food crop implies the quantity, range and quality of energy (calories), vitamins, minerals and phytochemicals in that particular food crop. Several studies in South Africa have evaluated nutritional value of NUS and reports allude to the fact that they supersede that of related common food crops. The micronutrient content of NUS has been shown to be species specific suggesting that not all NUS may be nutrient dense. This again speaks to the need to identify specific NUS that are drought tolerant and nutrient dense that can the target of research and development. In general, African leafy vegetables contain substantial amounts of carotenoids (lutein and β-carotene), iron, folate, riboflavin and calcium (Uusiku et al., 2010). Many of the known underutilized legumes (such as *Mucuna spp*., *Canavalia spp*., *Sesbania spp.*) are said to have higher amounts of protein, essential amino acids, polyunsaturated fatty acids, dietary fibre, and essential minerals and vitamins in comparison to other common legumes, along with the presence of beneficial bioactive compounds (Fasoyiro et al., 2006). However, dark green leafy vegetables are known to contain oxalates, phytates and nitrates, compounds that reduce absorption of certain micronutrients while anti-nutritional compounds such as total free phenolics, tannins, L-DOPA, trypsin inhibitor activity and phytohaemaglutinating activity also were found to be considerably high in these legumes (Wang et al., 2015). Research and development could aid in developing appropriate post-harvest and handling and processing technologies that would ensure that the benefits of nutrient dense NUS are realised whilst minimising the anti–nutritional components.

The greatest impediment to utilizing NUS as a food and feed is the presence of certain anti-nutritional factors, which might not only be toxic, but also can be lethal in extreme situations. The removal of these anti-nutrients from NUS with minimal compromise on the nutritional qualities has been a great challenge for many food researchers (Acho et al., 2014; Fasoyiro et al., 2006; Igile et al., 2013; Mavengahama et al., 2013). However, the concentration and level of these anti-nutrients might vary between crop species and also among sub-accessions of the same species depending on the location of collection, stage of development, and availability. Nevertheless, it should be noted that some of the commonly considered anti-nutrient compounds like phenols and tannins are now being considered as potential antioxidants with health promoting effects (Bhat and Karim, 2009). Hence, depending on the consumer preferences retaining or eliminating these compounds could be facilitated given the appropriate agro-processing technique. Various modern and traditional food processing methodologies can be applied, and standardized, to either reduce or eliminate anti-nutritional factors/compounds in NUS. However, due to the immature value chains associated with NUS in South Africa, there is limited evidence suggesting that they part-take in any agro-processing activities. Although NUS may be nutrient dense, the presence of anti-nutritional factors and the inability to process and add value to NUS may act as a deterrent for their investment. Therefore, to reposition the neglected crops species so that they have an equal standing in nation and global markets, there is need to come up with agro-processing techniques that will add value and relevance to the end product.

1.5.2 Potential of NUS in Smallholder Farming Systems

South Africa is generally classified as being semi-arid and its water profile is rapidly moving from water scarce to water stressed (Singels et al., 2010). The country's annual average rainfall fluctuates around 500 mm, which is far below the world's average of 860 mm per annum (Blignaut et al., 2009). Rainfall is unevenly distributed, with about 50% of the rain falling on 15% of the land (Crétat et al., 2012). It is in most of the remaining 85% of the country where smallholder farming communities are concentrated (Shackleton et al., 2008). It is in the same areas where there are high incidences of food insecurity, malnutrition and poverty. In rural areas, agriculture remains the main livelihood activity although is practised on highly degraded soils with limited use of external inputs such as fertilisers and improved varieties.

Under these circumstances, crop productivity is low and there are significant yield gaps. The dependence on rainfed agriculture is also a primary major limitation and reason for the underlying low crop productivity. Part of the solution to this could involve including crops that are drought tolerant, with low water requirement and adapted to low input systems as part of the crop choice. The low productivity exposes farmers in these areas to chronic food insecurity. Agriculture is faced with 'a balancing act' of three needs where it must (i) increase in an environmentally friendly manner while at the same time contributing towards (ii) food and nutritional security and (iii) socio-economic development. It is in this context that the inclusion of NUS into crop systems of smallholder farmers should be promoted as they have immense potential to mitigate nutritional and water constraints.

Underutilised crops are a part of a large repository of plant genetic resource and possess numerous traits that allow them to confer resilience to drought, and even heat stress (Chivenge et al., 2015; Modi and Mabhaudhi, 2013; Vorster, 2007). This is mostly attributed to their having undergone rigorous cycles of selection and cultivation by farmers residing in mostly drought prone and harsh areas (Mabhaudhi et al., 2016b). This makes NUS important "future" crops since South Africa is projected to become drier due to climate change (Ziervogel et al., 2014). Their inclusion into existing cropping systems in marginal may increase overall resilience by widening the crop genetic pool thus increasing agro-biodiversity. In this regard, they could be used to contribute towards sustainable intensification of rural cropping systems. Secondly, most NUS are nutrient dense and can provide excellent sources of protein, minerals and vitamins to alleviate the 'hidden hunger' of micronutrient malnutrition that affects poor rural communities (Oelofse & Averbeke, 2012; Uusiku et al., 2010; van Rensburg et al., 2007). The combination of abiotic stress tolerance and nutrient density implies that they could contribute to food and nutritional security in marginal agricultural production areas (Mabhaudhi et al., 2016a). Their inherent diversity also has potential to broaden rural food baskets which currently lack dietary diversity. Thirdly, the fact that NUS value chains are underdeveloped creates opportunities for developing autonomous pathways out of poverty through promoting them in rural areas (Mabhaudhi et al., 2016b). In this regard, they can contribute to employment and wealth creation through opening new opportunities.

1.6 OPPORTUNITIES AND CHALLENGES FOR NUS IN SOUTH AFRICA

1.6.1 Opportunities

South Africa's food and agricultural-related policy frameworks reveals that there are many opportunities that can be harnessed from the production and utilisation of NUS in national development. One such policy framework is the National Policy on Food and Nutrition Security (NPFNS) (DAFF, 2013). Among the key objectives of the NPFNS are to promote research and development of NUS and increase their utilisation at a household level of people exposed to food and nutrition insecurity. As one of the major ways of achieving its objectives, the policy framework aims to promote and diversify food production by promoting the utilisation of NUS within farming systems dominated by cereal based cropping systems. They are now considered as a significant complement to 'major' food crops and serve to prevent the hidden hunger which is prevalent in rural communities in South Africa, and the elsewhere. The NPFNS, together with other agricultural developmental polices acknowledge that increasing dietary diversity is an important strategy to improve nutrition and health. This is also in line with SDG 1 – 3 that address issues to do with poverty, food and nutrition security, and health. While increasing the productivity of major cereal crops remains a continuous objective, policy frameworks have broadened their scopes to include the promotion of NUS as a cornerstone for increased dietary diversity. Their incorporation into existing cropping systems presents a win-win situation for increased agro-biodiversity and dietary diversity with the ultimate objective to improve food and nutrition security.

Smallholder farmers are often characterised as being resource poor lacking necessary financial, functional and structural support for rainfed agriculture. In addition, agro-ecological zones in which smallholder farming communities reside are characterised as unsuitable for rainfed farming activities. Besides socio-economic issues and bio-physical environmental conditions, it has been observed that climate change and variability has increased risk towards rainfed crop production systems due to shifting lengths of growing seasons, increased incidences and duration of dry spells and flash floods (Cooper et al., 2008; Shindell et al., 2012; Wheeler and von Braun, 2013; Rosegrant et al., 2014) and this further confounds the situation. Overall, existing cropping systems often succumb to water stress resulting in low productivity and even total crop failures. Under resource poor farming systems, many underutilized crop species have been observed to require few external inputs for production. While they may be less productive in comparison to improved major crops, their performance is relatively stable across different environmental conditions, especially in the event of extreme weather conditions such as drought and heat stress. Within resource constrained farming systems, and where there is considerable water limitation, NUS are a low input technology that can improve productivity under semi-arid conditions.

As a way of improving access of smallholder farmers to national and international agricultural markets, the production and marketing of NUS present for linking rural farmers to niche markets. In this regard, NUS are capable of supplying new food products and raw materials for industrial use. This creates new opportunities for income generation for smallholder communities who have not been able to participate in value chains of major crops. In addition, the ability of modern technologies such as biotechnology and various other agro-processing technologies to transform NUS into diverse products, making them more palatable and extend their shelf-life, can create new opportunities through innovation and developing new uses for NUS.

The promotion of drought tolerant and nutrient dense NUS also offers unique opportunities to address several of the Sustainable Development Goals (SDGs) as follows:

- achieving dietary diversity – SDG 1: end poverty in all forms everywhere; SDG 2: end hunger, achieve food security and improved nutrition and promote sustainable agriculture; SDG 3: ensure healthy lives and promote well-being for all ages;

- employment creation – SDG 1: end poverty in all forms everywhere; SDG 8: promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; and

- mitigating drought and water scarcity – SDG 15: protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

1.6.2 Challenges

An overarching challenge for the promotion and utilisation of NUS in South Africa and elsewhere is the absence of well-developed, supported and tested value chains. Many underutilised crops are almost exclusively for the farmers' own subsistence, even where potential exists to produce and market them more extensively. Empirical information required to formulate a sustainable food value chain is largely anecdotal and non-repetitive in that most available information is site specific.

There are significant gaps with regards to literature concerning underutilised crops. This is mostly attributed to the lack of focused research and development initiatives and infrastructure for upscaling and marketing products of suitable quality and in appropriate quantities to potential customers. This has created challenges in formulating strategies for scaling up production of NUS and their products within smallholder farming communities. To expand the scale of production, efficient technologies must be developed for manufacturing, storage and processing, to ensure that quality standards can be met.

Within smallholder farming communities in South Africa, and elsewhere, the social perceptions attached to NUS may lead to their low adoption into existing cropping systems. In many instances, NUS have been perceived as being "low status", "backward" or "old fashioned" in comparison to major crop species. As a result, many of the younger generations partaking in smallholder farming activities may not be willing to adopt NUS. Many researchers have indicated that NUS and indigenous knowledge systems attached to them are at risk of erosion since the remaining custodians are elderly. The social barriers regarding the possible promotion and uptake of NUS could be that information on their benefits is not easily accessible making it difficult to articulate and utilise NUS as a livelihood strategy. To do away with negative perceptions attached to NUS and increase their adoption, modern technologies need to be promoted alongside so as to incentivise the younger generations. This requires that information regarding their nutrition, agronomy and agro-processing be generated.

The lack of robust empirical and comparable information describing basic aspects of NUS such as their agronomy and ecophysiology means that a lot is left is to anecdotal evidence (Mabhaudhi et al., 2016b). This could act as a disincentive for governments and major funders to invest in their research and development. According to Padulosi et al. (2013), the main agronomic challenges affecting the promotion of NUS include (i) insufficient, and at times lack of propagation material and seed owing to informal seed market systems, (ii) insufficiently trained human resources who possess the technical aspects of producing NUS, and (iii) poor support from research and development into best management options with regards to the crop, soil, fertiliser and, pest and weed. This analysis is consistent with the status of NUS in South Africa and remains an obstacle to the sustainable promotion and utilisation of NUS.

1.7 RECOMMENDATIONS

Based on the evidence presented, the following recommendations were developed:

- Research and development of NUS should prioritise those NUS that are drought tolerant and nutrient dense and adapted to a range of environments in South Africa;
- An initial starting pointing is to develop a consensus definition for NUS that aligns with global trends. This will allow for ease of archiving and comparing data sets on underutilised crops;
- Focussing on a few priority species would allow for improved allocation of limited resources to fund the research and development;
- In order to achieve impact at scale and in a short period of time, the value chain approach should be used as a template for developing a research and development strategy for South Africa. This, combined with focus on a few priority species, will provide credible success stories that can be used to promote other NUS;
- Land suitability mapping should also include the priority NUS so that they can be included in the crop choice available to farmers; and
- On this basis, priority NUS could be included in the crop choice for climate change adaptation and addressing food and nutrition security in South Africa.

1.8 CONCLUSION

South Africa has made plausible strides in research on underutilised crops. There is need to consolidate the research that has been done to bring it to scale and make an impact. The fact that most underutilised crops are drought tolerant and nutrient dense makes them an important resource for addressing key challenges of (i) improving food and nutrition security, (ii) under water scarcity, and (iii) in a changing climate. Given the timeframes, it is suggested that focus should be on a few priority underutilised crops that best exemplify these attributes. Adopting a value chain approach to underutilised crops' research and development offers significant potential for developing new and autonomous pathways for sustainably increasing production and alleviating rural poverty. Focussing on key underutilised crops and developing their value chains also offers an opportunity for addressing several of the SDGs.

CHAPTER 2
PRIORITY UNDERUTILISED CROPS FOR SOUTH AFRICA

T. Mabhaudhi, T.P. Chibarabada and A.T. Modi

2.1 INTRODUCTION

The history of mankind has been that of narrowing genetic diversity in terms of food sources. Records show that there are between 300 000 to 500 000 plant species in existence, of which 30 000 are reported to be edible (Garn and Leonard, 1989). Collins and Qualset (1998) stated that of the 30 000 edible plant species, only 7 000 species have actually ever been utilised as food sources by humankind. They argued that of this diversity, only 20 species accounted for 90% of global food requirements, with wheat, maize and rice accounting for at least 60% of global food intake (Collins and Qualset, 1998). According to Modi et al. (2006), the traditional crops grown in most parts of South Africa were maize, beans, potatoes, pumpkins and groundnuts. This is despite the fact that South Africa is regarded as a mega-diverse country. While the world's now major crops have succeeded in ensuring food security for most of the world, their ability to continue to deliver on food and nutrition security challenges in the 21st century is now being challenged (Mabhaudhi et al., 2016b).

Increasing population growth, affluence and pressure on finite land and water resources are threatening global food security. Concurrently, ongoing climate change and variability have a multiplier effect on several of these stresses, especially water availability. This has necessitated a paradigm shift in agriculture with calls to explore underutilised crops as possible future crops (Chivenge et al., 2015; Mabhaudhi et al., 2016a). These calls are premised on widely held assumptions that underutilised crops are tolerant to a range of abiotic and biotic stresses (Chivenge et al., 2015). In addition, there are also reports that many of these underutilised crops are nutrient dense. They also represent sustainable agriculture in that they tend to be adapted to the local environments in which they exist and are adapted to low input agricultural systems.

In South Africa, which is a water stressed country, these attributes have reignited interest in underutilised crops. Of critical importance is their perceived drought tolerance and nutritional value. This could prove useful during periods of drought such as the 2015/16 drought that devastated huge parts of southern Africa. Under such conditions, underutilised crops could be promoted in marginal agricultural production areas which is where most rural areas are located. Here, underutilised crops have potential to offer opportunities for building resilience and diversifying the diets of rural people. However, much of the potential of underutilised crops is currently premised on anecdotal evidence with limited robust and comparable information (Modi and Mabhaudhi, 2013). Thus, there is a need to generate such information as this would greatly assist in policy formulation (Modi and Mabhaudhi, 2013). Cognisant of this need, over the recent past, organisations such as the Water Research Commission of South Africa and the national Department of Science and Technology have been funding research aimed at determining water use, drought tolerance, agronomy and nutritional value of several underutilised crops.

There is also an emerging wider recognition that underutilised crops could play a role in strengthening rural farming and cropping systems (Williams and Haq, 2000) as well as creating new opportunities for rural economic development through the development of new value chains. While all this is positive for underutilised crops' development, there are still significant obstacles. Despite ongoing efforts, research, development and innovation on underutilised crops in South Africa was still limited (*cf.* **Chapter 1**). There were major gaps with respect to all aspects of underutilised crops value chains. The initial deliverable recommended that, as a way forward, there was need to identify priority underutilised crops. This would allow for the limited resources available to be directed towards specific underutilised crops that offered the most prospects for success.

For South Africa, such prioritisation should be aligned to current and future challenges such as drought and food and nutrition insecurity. This implies that prioritisation should focus primarily on identifying those underutilised crops that are drought tolerant and nutrient dense. In addition, nutrition is also about diversity, hence the prioritisation should also aim to include a range of crop categories and shift from the dominance of cereal and starchy crops. Furthermore, for the prioritisation and promotion of underutilised crops to be successful, there needs to be champions who will drive research, development and innovation focussed on priority underutilised crops. In this regards, Dansi et al. (2012) emphasised that there was a need for "well-trained and motivated African agricultural scientists" if the promotion of underutilised crops was to be successful.

The aim of the current report was therefore to identify; (i) the range of underutilised crops that have been researched in South Africa, (ii) the thematic research areas on underutilised crops, (iii) drought tolerant and nutrient dense underutilised crops, and (iv) researchers who have been championing underutilised crops research in South Africa. The work that is reported in the current report will then contribute to articulating a research strategy for the identified priority drought tolerant and nutrient dense underutilised crops for South Africa.

2.2 METHODOLOGY

In order to develop a list of drought tolerant and nutrient dense underutilised crops for South Africa, a phased approach was adopted. The methodology adapted for the study was split into three phases, namely, (i) literature search, (ii) resource identification, and (iii) prioritisation. Details for each of the phases are described in detail below.

2.2.1 Phase 1: Literature Search

For the literature review, a mixed method approach which included combining quantitative and qualitative research or outcomes with process studies was used. Emphasis was placed exclusively on identifying literature on underutilised crops from South Africa. Briefly, the study initially identified the terms or key words commonly used to refer to underutilised crops in South African literature (*cf*. **Section 1.3**). From this exercise, the five (5) commonly used terms that were identified included; (i) underutilised crops, (ii) indigenous crops, (iii) traditional crops, (iv) neglected crops, and (v) orphan crops. Thereafter, these terms were used to conduct online searches using Google® and Google Scholar® search engines. Google® and Google Scholar® were assigned to search for the identified key words 'anywhere in the text'. The interest was to confine the search to South African literature hence Google® and Google Scholar® were set to filter results to the country South Africa. Results were further filtered to only show results that featured at least one of the exact words 'underutilised/indigenous/traditional/neglected/orphan'.

Following this, the results found were then separated into pre– and post–2000 time periods. Furthermore, documented results were separated into scientific, public and online publications. Scientific articles included research papers, theses, conference proceedings and technical reports. Public articles included government and non-government gazettes and reports. Online articles included information that was primarily only published on websites of respectable organisations.

2.2.2 Phase 2: Resource Identification

The overall aim of Phase 2 was to use outputs of Phase 1 to (i) identify experts who have published on specific underutilised crops, and (ii) establish their track record i.e. number of publications and consistency on a specific underutilised crop. Following from Phase 1, a resource identification sheet (*cf*. **Appendix 1**) was completed for each resource identified during the initial literature search. The specific objectives of Phase 2 were then to further categorise the identified sources on the basis of (i) common underutilised crops, (ii) research themes, and (iii) leading authors and institutions with regard to research on underutilised crops. The resource identification was also developed as an initial step towards developing a tool for archiving information on and developing a database for underutilised crops.

i. The crops that were identified included bambara groundnut (*Vigna subterranea* (L.), amaranth (*Amaranthus sp*.), bottle gourd (*Lagenaria siceraria*), maize landraces (*Zea mays*), cowpea (*Vigna unguiculata* (L.) Walp), sweet-potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), sword bean (*Canavalia gladiate*), black jack (*Bidens pilosa*), marama bean (*Tylosema esculentum*) jews mallow (*Corchorus olitorius*), spider plant (*Cleome gynandra*), pearl millet (*Eleusine coracana*), nightshade (*Solanum nigrum*), chinese cabbage (*Brassica chinensis*), cocoyam (*Xanthosoma spp*.), sunberry (*Solanum nigrum*), wild water melon (*Citrullus lanatus*), wild mustard (*Sinapis arvensis*), sorghum (*Sorghum bicolour*), sesame (*Sesamum indicum* L.) and teff (*Eragrostis tef*).

ii. Common research themes identified included nutrition, ecophysiology, agronomy, crop modelling, food security, seed quality, public articles, breeding, perceptions, climate change, postharvest technology, genetic resources, medicinal properties, commercialisation and biotechnology. Concurrently, the amount of research per crop per research theme were also recorded. The objective of this parallel exercise was to provide an initial assessment of gaps in knowledge on identified underutilised crops in relation to the thematic areas of research.

iii. Authors were ranked according to the number of publications featured irrespective of being first author or co-author. A criterion for inclusion was that author(s) should have published at least two publications across the spectrum of publications and research themes considered in this study. To establish the authors' most common theme(s) of interest, the number of publications in a certain theme was listed. This contributed to the total number of publications by the author(s). As an initial attempt to identifying champions within the identified research thematic areas, the criteria was such that 'a researcher should have at least two or more publications in that certain theme in order to be listed as a champion'. Using that criteria, champions in the different themes were listed.

2.2.3 Phase 3: Identifying Priority Underutilised Crops

The objective of this phase was to develop a list of priority drought tolerant and nutrient dense underutilised crops for South Africa. Initially, the list of priority underutilised crops for research in Africa proposed by Williams and Haq (2000) was used as a baseline for the current study. The underutilised crops listed by Williams and Haq (2000) were then compared to the underutilised crops currently researched in South Africa.

Thereafter, literature search on drought tolerance, heat stress tolerance and nutrient density was conducted *viz*. the initial list of underutilised crops identified in South Africa's literature. The objective of this phase was to identify an initial priority list of underutilised crops of interest in South Africa based on drought tolerance and nutrient density of the different categories of crops (cereals, legumes, vegetables, roots and tuber crops). Crops that had been reported in the literature as being drought tolerant, heat stress tolerant and that were nutrient dense, based on available publications, were then identified. Based on this, a list of drought tolerant and nutrient dense priority underutilised crops was developed. The list still recognised the established crop categories of cereals, legumes, leafy vegetables and root and tuber crops.

Lastly, a crop data sheet (*cf*. **Appendix 2**) was developed for each of the identified drought tolerant and nutrient dense priority underutilised crops. The fact sheets will contribute to developing a database on priority underutilised crops for South Africa.

2.3 RESULTS AND DISCUSSION

2.3.1 Initial Literature Search

During the initial literature search we observed that in South Africa, 'traditional crops' was the most popular term with 236 000 hits returned on Google®, while 'indigenous crops' was the least popular with 1110 hits returned on Google® (Table 2.1). When results were filtered to only show results that featured at least one of the exact words 'underutilised/indigenous/traditional/neglected/orphan', 'neglected crops' became the most popular term with 35 000 and 112 000 hits returned on Google® and Google Scholar®, respectively. It was observed that 'underutilised' and 'orphan crops' were the least popular terms based on results found on both Google® and Google Scholar®. The use of so many terms confirmed earlier observations that there is a need for a consensus definition (*cf.* **Section 1.3**). Depending on which term one uses to refer to underutilised crops, that could limit the amount of information they may access. This implies that the lack of a consensus definition risks information on underutilised crops being scattered thus unable to make impact on global and local knowledge development. The need for a consensus definition for underutilised crops has previously been emphasised by (Chivenge et al., 2015; Mabhaudhi et al., 2016b)

For all the terms used in the literature search, there was at least 10 times more literature during the post–2000 when compared to the pre–2000 for both Google® and Google Scholar® search engines (Table 2.1). From the literature search exercise, 81 scientific articles, five public articles and three organisation websites that were relevant to our objectives were extracted and documented for Resource Identification (Table 2.1).

2.3.2 Resource Identification

Results of resource identification showed that the most researched themes on NUS were nutrition and ecophysiology with 15 and 14 publications, respectively. This was followed by seed quality and food security, each with 11 publications. Themes that featured in four to six publications were agronomy, public articles, crop modelling and genetic resources. Themes that had the least number of publications (< 3) were climate change, breeding, peoples' perceptions, medicinal properties, commercialisation and biotechnology (Table 2.2). This highlights that much of the work that has been done on underutilised crops in South Africa is in line with national priorities of addressing tolerance to abiotic stresses (drought and heat) and nutritional goals with respect to food and nutrition security.

With respect to crops, vegetable crops generally received the most research attention with amaranth being the most researched vegetable crop. This confirmed reports on the status of underutilised crops in South Africa that of all the crop categories, leafy vegetables had received the most research attention (*cf*. **Section 1.5**). Within the legume category of crops, bambara groundnut and cowpea were the most researched crops with 14 and 6 publications, respectively. The high number of publications on bambara groundnut also aligns with international efforts being driven by the Bambara Groundnut Network (BamNetwork) to promote bambara groundnut as an exemplar underutilised crop (www.bambaragroundnut.org). Among the cereal crops, maize landraces and sorghum were the highest with four and three publications, respectively. With respect to root and tuber crops taro received the most research attention (12 publications) followed by sweet-potato (three publications) (Table 2.2).

2.3.2.1 Identifying local researchers and research gaps

A major objective of the resource identification exercise was to identify South African researchers and institutions that have been working on underutilised crops. Secondary to this, was the need to identify the areas that have received research attention and the existing research gaps with regards to knowledge on underutilised crops. At this stage, it is also prudent that we acknowledge that due to the approach that was used to search for information on underutilised crops and the criteria thereof, some researchers and institutions may have been unintentionally excluded.

Table 2.3 provides an indication of the spectrum of South African researchers that have published on underutilised crops. Most of the identified researchers have published on more than one theme (Table 2.4). This highlights that the researchers have interests that span various aspects of the underutilised crops value chain. Another trend, most of the researchers were mostly from academic and research institutions with very few official publications from government departments such as the Department of Agriculture, Forestry and Fisheries (DAFF). This highlights another critical gap with regards to policy on underutilised crops. However, despite the lack of explicit policy on underutilised crops, it is encouraging to note that several researchers that were identified are in national agricultural research stations (NARS). This bodes well for the future of underutilised crops in South Africa.

The lack of national policy on underutilised crops has been previously highlighted (Mabhaudhi et al., 2016b; Padulosi et al., 2013; Williams and Haq, 2000). It is well recognised that most of the advances in research, development and innovation linked to the current major crops has been due to deliberate and supportive policy instruments highlighted (Padulosi et al., 2002). The development of policy is often a precursor to resource mobilisation. There is a greater need to articulate an explicit national policy at the government and research level on underutilised crops. In this regard, there is need to promote a policy dialogue on the role of underutilised crops in rural economic development and achieving food and nutrition security in rural South Africa.

Another point of concern is that researchers are highly skilled individuals who are very mobile. Therefore, the researchers identified in Tables 2.4 and 2.5, may have moved from their institutions and moved away from underutilised crops research as a whole. The need to develop and retain research skills on underutilised crops is thus crucial to the continuity or emerging research. In this regard, targeting champions could help ensure continuity and retention of research skills related to underutilised crops.

Table 2.1: Results of South African literature available on the Google and Google scholar engine for neglected underutilised crops.

	Underutilised Crops	**Indigenous Crops**	**Traditional Crops**	**Neglected Crops**	**Orphan Crops**
Google Search 'Total Results Found'	176 000	576 000	9 080 000	468 000	499 000
Google Scholar Search 'Total results found'	17 900	346 000	559 000	132,000	23,600
Filter: South Africa 'Google Search'	7720	1110	236 000	53 900	27 900
Filter: With the exact word 'Google Search'	108	377	648	35 000	85
Filter: With the exact word 'Google Scholar Search'	546	1660	3650	112 000	275
Filter: With the exact word and Pre-2000 'Google Search'	16	3	1	172	12
Filter: With the exact word and Pre-2000 'Google scholar Search'	6	299	729	17 500	12
Filter: With the exact word and Post- 2000 'Google Search'	126	237	89	4 600	785
Filter: With the exact word and Post 2000 'Google Scholar search'	531	1330	2890	19,100	261
Documented: Google scholar 'Scientific articles'	–	–	81	–	–
Documented: Google web 'Public articles'	–	–	5	–	–
Documented: 'Company websites'	–	–	3	–	–

NB. Results are based on South African literature only.

Table 2.2: List of crops and the number of times a crop was researched under a particular theme based on the South Africa resource identification search.

Crops	Total	Nutrition	Ecophysiology	Agronomy	Crop modelling	Food security	Seed quality	Popular articles	Breeding	Perceptions	Climate change	Post-harvest	Genetic variation	Medicinal properties	Commercialisation	Biotechnology
*ALVs	24	11	1	1	1	13	–	–	–	3	–	–	–	–	1	–
**ICs	15	1	3	2		7		4		–	1		1	–	1	–
B. groundnut	14		5	2	1		4		1	–	1			–	–	–
Amaranth	4	–	–	2	–	–	1	–	–	–	–	–	1	–	–	–
Bottle gourd	2	–	–		–	–	2	–	–	–	–	–	–	–	–	–
Maize landraces	4	–	–	1	–	–	3	–	–	–	–	–	–	–	–	–
Cowpea	6		1	2	1	–			2	–	–	–	–	–	–	–
Sweet-potato	3	1	–	–	–	–	2	–	–	–	–	–	–	–	–	–
Taro	12	1	4	2	2		–	–	–	–	1	1	1	–	–	–
Sword bean	1		–	–	–	1	–	–	–	–	–	–	–	–	–	–
Black jack	1		–	–	–	–	–	–	–	–	–	–	–	1	–	–
Marama bean	2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Jews Mallow	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Spider plant	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Finger Millet	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Nightshade	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–

Chinese Cabbage	1	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Cocoyam	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sunberry	1	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–
Wild mustard	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Sorghum	3	–	1	–	1	–	–	–	–	–	–	–	–	–	–	1
Sesame	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tef	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Wild water melon	3	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–

*ALVs =Indigenous leafy vegetables and refers to articles that have addressed indigenous, underutilised, wild, and traditional vegetables with no particular focus to any single leafy vegetable. **IC = Indigenous crops and refers to articles that have addressed indigenous, underutilised, wild, and traditional crops with no particular focus to any single crop.

Table 2.3: List of South African based researchers working on underutilised crop species including the themes that they have published on.

Author	*Resources co/authored	Themes of publications (in order of most published)
Modi AT	37	Eco-physiology (10), Seed Quality (9), Crop Modelling (3), Agronomy (3), Postharvest Technology (1), Nutrition (1), Genetic Resources (1), Promoting Awareness (1)
Mabhaudhi T	36	Ecophysiology (9), Seed Quality (7), Crop Modelling (4), Climate Change (3), Agronomy (2), Nutrition (2), Genetic Resources (1), Promoting Awareness (1)
Beletse YG	10	Ecophysiology (4), Crop Modelling (3), Agronomy (2), Commercialisation (1)
van Rensburg WS	5	Food security (2), Genetic Resources (1), Nutrition (2), Breeding (1)
van Averbeke W	4	Commercialisation (1), Nutrition (2), Agronomy (1), Ecophysiology (1)
Goduka I	4	Medicinal properties (2), Nutrition (1), Perceptions (1)
Njume C	3	Medicinal properties (2), Nutrition (1)
Mavengahama S	3	Food security (2), Agronomy (1)
Ayodele VI	3	Agronomy (2), Food Security (1)
Afolayan AJ	3	Nutrition (2), Food Security (1)
Adebola PO	3	Genetic Resources (1), Nutrition (1), Food Security (1)
Vorster HJ	3	Food security (2), Agronomy (1)
Motsa NM	2	Food Security (2), Nutrition (1)
Slabbert R	2	Ecophysiology (1), Nutrition (1)
Faber M	2	Nutrition (2), Perceptions (1)
De Ronde JA	2	Food Security (1), Breeding (1)
Gerrano AS	3	Food Security (1), Genetic Resources (1), Breeding (1)
Spreeth MH	2	Breeding (1), Eco-Physiology (1)
Schonfeldt HC	2	Nutrition (2)
Reinsten F	2	Commercialisation (1), Genetic Resources (1)
Coetzee JH	2	Commercialisation (1), Genetic Resources (1)
Kunz R	2	Climate Change (2)
George G	2	Nutrition (1), Medicinal Properties (1)
Gqaza BM	2	Medicinal properties(2)
Oelefse A	2	Nutrition (1), Eco-physiology (1)
van De Heever	2	Food security (2), Nutrition (1)
Walker S	3	Food security (1), Crop Modelling (2)
DAFF	3	Public Articles

*Based on the resource identification exercise. Authors may have published more papers than those that were identified during the online search.

Table 2.4: List of themes that have been researched in South Africa and the South African based researchers that have published two or more publications on that theme.

Themes	**†Number of Publications**	**Authors with 2 or more publications**
Nutrition	15	Afolayan AJ, Schonfeldt HC, Mabhaudhi T, Faber M, Van Averbeke, van Rensburg WS
Ecophysiology	14	Modi AT, Mabhaudhi T, Beletse Y.G, Van Averbeke
Agronomy	6	Modi AT, Mabhaudhi T, Beletse Y.G, Ayodele VI,
Crop Modelling	4	Modi AT, Mabhaudhi T, Beletse Y.G, Walker S
Food security	11	Vorster HJ, Motsa NM, Modi AT, Mabhaudhi T, van Rensburg WS, Mavengahama S, van De Heever
Seed quality	11	Modi AT, Mabhaudhi T, Chibarabada TP
Public articles	5	DAFF
Breeding	2	De Ronde JA*, Spreeth MH* van Rensburg WS* Gerrano AS
Perceptions	2	Goduka I, Faber M
Climate change	3	Mabhaudhi T
Postharvest technology	1	Modi AT*
Genetic Resources	4	van Rensburg WS*, Adebola PO*, Gerrano AS*
Medicinal Properties	2	Goduka I, Njume C, Gqaza BM
Commercialisation	2	van Averbeke W*, Reinsten F*, Coetzee JH*, Beletse Y.G*, Van Averbeke*
Biotechnology	1	M.M. O'Kennedy*, A. Grootboom*, P.R. Shewry*

†Publications referred to include all the documented publications (publications, reports, conference proceedings and online articles). * Refers to authors that did not meet the two publications for some certain theme criteria but are only listed because they are the only ones that published on that theme.

2.3.3 Identifying Priority Underutilised Crops

A major objective of the current report was to develop a list of priority underutilised crops for South Africa. A major criterion that was set was that such crops should be drought tolerant and nutrient dense. As an initial step to identifying priority underutilised crops for South Africa, the identified underutilised crops from local research (Table 2.2) were compared to the African list of priority underutilised crops that was developed by Williams and Haq (2000) (Table 2.5).

Results of the comparison of underutilised crops listed by Williams and Haq (2000)to those currently researched in South Africa showed that a positive match for 12 locally researched underutilised crops featured and those on the list by Williams and Haq (2000) (Table 2.5). Among the cereal crops, only finger millet featured on both lists while for legumes, bambara groundnut, swordbean and lablab were the three legumes that featured on both lists. Taro and cocoyam were the two root and tuber crops that featured on both the list by Williams and Haq (2000) and list of underutilised crops currently being researched in South Africa. The exclusion of locally underutilised crops such as cowpea, pigeon pea, sorghum, tef, sweet potato and maize landraces was attributed to global definitions of underutilised crops and the reference to “where, when and by who” (Padulosi, 2006) that is often applied when defining underutilised. This implies that a crop may be underutilised in South Africa but not necessarily elsewhere. This is the case with crops such as sorghum and tef which are important in other African countries.

The majority of crops on both lists (Williams and Haq, 2000) and crops currently being researched in South Africa were vegetable crops i.e. bottle gourd, blackjack, jews mallow, amaranth, nightshade, wild water melon and chinese cabbage (Table 2.5). This confirmed the dominance of indigenous leafy vegetables within the family of underutilised crops. Modi (2015) also reported that several of these indigenous leafy vegetables had significant nutritional potential to contribute to the diets of rural people. They noted that indigenous leafy vegetables had previously formed an important aspect of rural diets but were now on the decline.

There were also crops that featured on the list of Africa’s priority crops by Williams and Haq (2000) which did not appear on the list of underutilised crops that are currently being researched in South Africa. These include barnyard grass, velvet bean, cassava, African yam bean, African egg-plant and roselle (Table 2.5). It may be that some of these crops are already been researched in South Africa but did not come up in the initial literature search that was conducted.

Table 2.5: A comparison of crops that are listed as priority crops for Africa and crops that are currently researched in South Africa.

	Common name	***Priority crops for Africa**	****Currently researched in South Africa**
Cereals	Sorghum		X
	Finger Millet	X	X
	Tef		X
	Maize landraces		X
	Barnyard grass	X	
Legumes	Bambara nut	X	X
	Lablab	X	X
	Pigeon pea		
	Sword bean	X	X
	Cowpea		X
	Velvet bean	X	
	Marama bean		X
Root and tubers	Taro	X	X
	Sweet-potato		X
	Cassava	X	
	African yam bean	X	
	Cocoyam	X	X
Vegetables	Bottle gourd	X	X
	Black jack	X	X
	African Eggplant	X	
	Jews Mallow	X	X
	Roselle	X	
	Spider plant		X
	Amaranth	X	X
	Nightshade	X	X
	Chinese Cabbage	X	X
	Sunberry		X
	Wild mustard		X
	Wild Water Melon	X	X

*Obtained from Global Research on Underutilised Crops an Assessment of Current Activities and Proposals for Enhanced Cooperation (Williams and Haq, 2000). **Includes Crops obtained from the database created from this study on underutilised crops that are currently featuring in South African research.

2.3.3.1 Priority underutilised crops for South Africa

To further identify underutilised crops of interest in South Africa we conducted a literature search for drought stress tolerance, heat stress tolerance and nutritional composition for underutilised crops from South Africa (Table 2.6 and 2.7). The aim was to identify crops that exhibited qualities of drought stress tolerance, heat stress tolerance (Table 2.6) and were nutrient dense (Table 2.7). Based on these criteria, a total of 13 underutilised crops, split into cereals, legumes, root and tuber crops and leafy vegetables, were identified as priority drought tolerant and nutrient dense underutilised crops (Table 2.8). The list was dominated by leafy vegetables.

Table 2.6: Underutilised crops of interest in South Africa categorized into cereals, legumes, vegetables, roots and tuber crops.

	Common name	Scientific Name	Drought Tolerance	Heat Stress Tolerance	Publications
Cereals	Sorghum	*Sorghum bicolor*	*		3
	Finger Millet	*Eleusine coracana*			1
	Teff	*Eragrostis tef*		X	1
	Maize landraces	*Zea mays*			4
Legumes	Bambara groundnut	*Vigna subterranea* (L.)	*		14
	Lablab	*Lablab purpureus* (L.) *Sweet*			1
	Sword bean	*Canavalia gladiate*		X	1
	Cowpea	*Vigna unguiculata* (L.) *Walp*	*		6
	Marama bean	*Tylosema esculentum*			2
Root and tubers	Taro	*Colocasia esculenta*	*		12
	Sweet-potato	*Ipomoea batatas*	*		3
	Cocoyam	*Xanthosoma spp.*			1
Vegetables	Bottle gourd	*Lagenaria siceraria*			2
	Black jack	*Bidens pilosa*	*		1
	Jews Mallow	*Corchorus olitorius*	*		1
	Spider plant	*Cleome gynandra*	*		1
	Amaranth	*Amaranthus sp.*	*		4
	Nightshade	*Solanum nigrum*	*		1
	Chinese Cabbage	*Brassica chinensis*	*	X	1
	Sunberry	*Solanum retroflexum*			1
	Wild mustard	*Sinapis arvensis*			1
	Wild Water Melon	*Citrullus lanatus*			3

*The results have been shown on South African landraces and/or cultivars.

Table 2.7: Selected nutrition profile of underutilised crops currently researched in South Africa. (Nutritional values based on raw 100 g portion).

	Common name	Energy (kcal)	Protein (g)	Fat (g)	Fibre (g)	Ash	CHO (g)	Ca (mg)	P (mg)	Na (mg)	Mg (mg)	Cu (mg)	Zn (mg)	Fe (mg)
Cereals	Maize landraces	339	13,7	2,47	2,7	1,78	71	34	508	2	3,01	0,55	4,16	3,01
	Sorghum	329	10,9	3,2	2,3	1,6	73	27	215	4	103	0,3	1,5	2,6
	Finger millet	363	11	5	2,2	1,9	69	25	–	–	–	–	–	–
	Teff	367	13	2.4	8	2.49	73	0.19	13	0.01	354.18	–	37.30	50.78
Legumes	Bambara	386,32	21,85	6,9	3,42	3,6	53,39	219,26	266,1	11,9	2,6	0,41	7,9	7,02
	Cowpea	357,1	24,7	4,8	2,8	4,2	51,76	180,46	310,94	107,24	1,74	9,9	5,3	4,9
	Lablab	117	26.86	0.27		3.96	67.23	–	8	–	–	–	0.38	0.76
	Sword Bean	1560.3	28.39	7.84	8.23	5.63	49.91	–	–	–	–	–	–	–
	Marama bean	477	34.71	40.06	3.94	3.19	14.07	241	454	63.75	274.5	1.04	6.2	3.95
Root and Tuber Crops	Taro	102	7,79	0,65	3,01	2,44	86,11	55	1,6	–	–	–	1,67	–
	Sweet potato	86	1.6	0,1	3.0	1,05	20.1	30	47	55	25	3	249	0,42
	Cocoyam	112	1.5	0.2	4.1	–	26	–	–	–	–	–	–	–
Vegetables	Amaranth	49	4	0.2	2.87	3.42	7.86	1686	487	347	82	3	56	25
	Nightshade	55	3	0.6	2.42	2.24	9.03	2067	478	431	3	6	23	85
	Black jack	39	5	0.6	2.92	2.82	3.72	1354	504	290	21	10	22	17
	Jews Mallow	392	20.90	5.20	45.61	–	55.50	1760	490	801.20	15.50	11.30	12.40	53.30
	Wild mustard	26	2.7	0.2	1.1	1.4	4.9	–	–	–	–	–	–	–
	Bottle gourd	14	0.62	0.02	0.5	0.5	3.39	26	13	2	0.089	0.034	0.70	0.20
	Chinese Cabbage	21	9	1	1.0	1.4	22	152	32	29	42	0.07	0.30	1.4
	Sun–berry	38	5.8	0.8	1.4	8.8	5.0	442	75	–	–	–	–	4.2
	Spider plant	–	7.7	0.9	1.6	3	6.4	434	12	33.6	86	0.46	0.76	11
	Wild water melon	296	3.5	0.4	3.8	1.66	13.1	212	119	9	59	0.20	0.74	6.4

Table 2.8: List of priority drought tolerant and nutrient dense underutilised crops for South Africa.

	Common name	Scientific Name
Cereals	Sorghum	*Sorghum bicolor*
	Teff	*Eragrostis tef*
Legumes	Bambara groundnut	*Vigna subterranea* (L.)
	Lablab	*Lablab purpureus* (L.) Sweet
	Cowpea	*Vigna unguiculata* (L.) Walp
	Marama bean	*Tylosema esculentum*
Root and tubers	Taro	*Colocasia esculenta*
	Sweet-potato	*Ipomoea batatas*
Leafy vegetables	Jews Mallow	*Corchorus olitorius*
	Spider plant	*Cleome gynandra*
	Amaranth	*Amaranthus sp.*
	Nightshade	*Solanum nigrum*
	Wild Water Melon	*Citrullus Lanatus* L.

2.4 CONCLUSION

The South African research landscape shows that there has been emerging interest on underutilised crops, especially during the post–2000 period. A significant body of literature on underutilised crops currently exists. However, much of this information remains scattered as there lacks a consensus definition. This results in researchers often referring to underutilised crops by a wide range of names. This makes it challenging to fully appraise the body of work that has been undertaken on underutilised crops. A significant amount of South African research on underutilised crops has been directed on crop ecophysiology and nutritional value, with much of this research focussing on indigenous leafy vegetables. There are several researchers that were identified as champions as they have consistently published on underutilised crops. These should be targeted and supported in order to ensure capacity and retention of research skills on underutilised crops. A total of 13 underutilised crops were identified as priority underutilised crops, mostly based on their drought tolerance and nutritional value. The list of priority underutilised crops should be subjected to further scrutiny. In this regard, this report suggests that there should be a science/policy dialogue to finalise this list. Such a dialogue would include funders, government departments and agencies as well as the identified researchers from South Africa.

CHAPTER 3
GUIDELINES FOR FUTURE RESEARCH ON UNDERUTILISED CROPS

T. Mabhaudhi, V.G.P. Chimonyo and A.T. Modi

3.1 INTRODUCTION

Poor rural households still experience food and nutrition insecurity despite reports of South Africa being food secure (de Klerk et al., 2004). It is within these communities where the double burden of over– and under–nutrition continues to threaten livelihoods (Teka Tsegay et al., 2014) and, in particular, early childhood development (Mabhaudhi et al., 2016a). Many South African smallholder farmers rely of agriculture as a livelihood strategy (van Averbeke and Khosa, 2007). However, the current over-dependence on a few major crops, often not well-adapted to their harsh environments, by smallholder farmers in South Africa and across the region has fostered low resilience and productivity of cropping systems (Affholder et al., 2013). Furthermore, this has throttled the contribution of agriculture to food and nutrition security. The draft agenda supports the urgent need to restore diversity through increasing agro-biodiversity within rural cropping systems as a strategy to improve productivity, resilience and dietary diversity (Mabhaudhi et al., 2016b).

Most underutilised crops have been reported to be nutrient dense and highly adaptable to abiotic stresses such as heat and drought stress (Chivenge et al., 2015). Their vast genetic pool presents an important sub-set of agro-biodiversity; therefore, supporting landscape diversity in marginal cropping systems (Modi and Mabhaudhi, 2013). Although NUS are reported to possess an array of attractive attributes, their potential and value chains, in comparison to those of major crops, remain poorly developed due to a paucity in available research. While there has been emerging interest and research targeting several NUS, the draft strategy noted that this remains scant and scattered (*cf*. **Chapter 1**). While the WRC's current research agenda has yielded significant and tangible progress, there is a need now define new priorities (*cf*. **Chapter 2**) to ensure that the gains already achieved are sustained. It must be noted that the development and subsequent dominance of the current major crops has been underpinned by dynamic, targeted and deliberate research whose priorities continue to evolve to meet changing global demands. Thus, if NUS are to be successfully translated into "notably utilised crops", there is a need to articulate a dynamic, self-perpetuating strategy that addresses current and future needs for NUS in South Africa.

As previously alluded to (*cf*. **Section 1.5.1**), current research has mainly focussed on the start-up point of the value chain with limited support activities restricting the formulation of a comprehensive and coherent research, development and innovation agenda. In response to this gap, the WRC has recently commissioned new projects that focus on quantifying water use of underutilised crops along the entire value chain. Another concern raised was that available information on underutilised crops was fragmented and inadequate to holistically promote and elevate NUS into mainstream agriculture. thus, the draft strategy seeks to articulate an action plan for mainstreaming underutilised agriculture into existing farming and cropping systems. A key aspect of the draft strategy is that it clarifies the role of underutilised crops as alternative crops under drought and water scarcity and for addressing food and nutrition security. It must be stated clearly that unlike how major crops were promoted, the promotion of underutilised crops does not seek to replace existing major crops, but rather to compliment them through diversification of cropping systems, especially within those agro-ecologies where underutilised crops have comparative advantages.

There are differing views on how strategy on NUS should be developed. One school of thought advocates for adopting a similar style as that used to promote current major crops. A second school of thought argues that this approach would fail to capture the very essence of what NUS represent – diversity – and could inadvertently alienate the current users and progenitors of underutilised crops. Within the context of South Africa, the development of NUS has to address pertinent developmental issues to which agriculture is expected to contribute. These include addressing the poverty-unemployment-inequality nexus through which food and nutrition security may also be improved. In addition, the intervention of NUS should be within the context of South Africa’s water scarcity and thus offer solutions to improving agricultural productivity under increasing water scarcity. Therefore, the objective of this section was to outline a draft strategic framework for research, development and innovation for NUS within South Africa based on the research value chain approach.

3.2 METHODOLOGY

The draft strategy for underutilised crops in South Africa adopted a conceptual and theoretical framework approach (Houwer, 2007; Sinclair, 2007). This entailed the use of a mixed method review approach, which included combining quantitative and qualitative research or outcomes with process studies. The conceptual framework was akin to an inductive approach and synthesised existing concepts with regards to RDI relevant for underutilised crops in South Africa. Briefly, a theoretical framework is a deductive approach which assesses existing literature. Within the context of the draft strategy, a theoretical framework was used to identify key focus areas for RDI on underutilised crops for South Africa. The development of the draft strategy thus involved a three step approach, namely, (i) a diagnosis of challenges, obstacles and opportunities (*cf.* **Chapter 1**), (ii) priority setting and developing a framework for addressing challenges (*cf.* **Chapter 2**), and (iii) developing a guiding framework outlining coherent actions and activities for future funding of research, development and innovation on underutilised crops for South Africa (*cf.* **Section 3.3**).

3.3 DEVELOPING A RESEARCH AGENDA FOR NUS FOR SOUTH AFRICA

3.3.1 Considerations for the NUS Strategy

The primary goal for the draft strategy was to establish priorities for research, development and innovation for NUS that would guide future funding for underutilised crops at a national level. Importantly, the draft strategy was developed to be consistent with key national developmental objectives and programs as well as to reflect the needs of sector stakeholders. It also seeks to complement the WRC's current research agenda for underutilised crops that was informed by (i) drought and heat stress tolerance, (ii) water use and nutritional value, and (iii) nutritional water productivity (Backeberg and Sanewe, 2010; Backeberg, 2014). Through this research agenda, the WRC has funded several projects and contributed immensely to the generation of information on underutilised crops in South Africa. The WRC's strategy has also established South Africa as a champion on underutilised crops within the region as well as globally.

In this regard, and in order to maintain continuity, the draft strategy maintained the focus on drought and heat tolerance and nutritional value. The draft strategy also seeks to consolidate gains made through identifying existing gaps and opportunities, and recommending a new set of priorities for funding that offer best prospects for success. The strategic plan establishes a clear commitment to delivering a series of actionable activities that encompass a new paradigm for NUS research and development. This approach covers not only conventional research but also the use of innovation platforms, policy, markets, advocacy, knowledge management, and the involvement of a broad base of stakeholders (Figure 3.1).

It is envisaged that through this draft strategy, NUS could be transformed into playing a key role in addressing pressing challenges related to food and nutrition security under water scarcity, informing climate change adaptation strategies and addressing the poverty-unemployment-inequality nexus. The translation of underutilised crops into notable successes commercially should thus be underpinned on research, development and innovation across the research value chain. Importantly, the draft strategy places emphasis on an adaptive strategy capable of responding to changing global paradigms and priorities. A key aspect of the strategy would be to ensure proper knowledge management of all information generated on underutilised crops. The knowledge management would thus contribute to the goal of establishing a database for underutilised crops.

3.3.2 Setting Priorities

3.3.2.1 Adaptive research

Within smallholder farming systems, agricultural production is complex owing to the varying levels of socio-economic and bio-physical constraints. As such, the promotion of any new technology should not assume a ‘one size fits all’ approach. In the past, such assumptions have resulted in low adoption of technologies that had achieved successes with regards to improving productivity in different geographic locations or in the past. In this regard, the draft RDI strategy for NUS seeks to prioritise end users’ needs, norms and values. With regards to NUS, these are often inextricable to the intrinsic value that such crops hold within the communities that have preserved and still utilise them. In this regard, several inter-related components such as (i) development of appropriate technologies, (ii) dissemination to end users, and (iii) diagnosis of impacts, and (iv) redefining and/or customising technologies are key to the draft strategy.

Adaptive research aims at devising site specific dynamic technology packages for increasing agricultural production (Lindenmayer and Likens, 2009). It helps to translate the results of research into suitable forms before transmitting it to farmers, making research more relevant to their local agro-climatic and socio-economic conditions. Adaptive research bridges the gap between research findings and farmers’ achievements and extension and consolidates knowledge on the subject matter. Therefore, one of the main goals of the RDI draft strategy plan for NUS focusses on adaptive research. For adaptive research to be a core pillar within the draft strategy, information should be readily available and accessible in a format suitable for the different end users. The WRC’s emphasis on community engagement and dissemination of research outputs through various platforms is a positive step towards such adaptive research.

An additional feature of this strategic framework, would be to promote a system for knowledge management which reflects current initiatives to develop dynamic and resilient protocols for the promotion of NUS in South Africa.

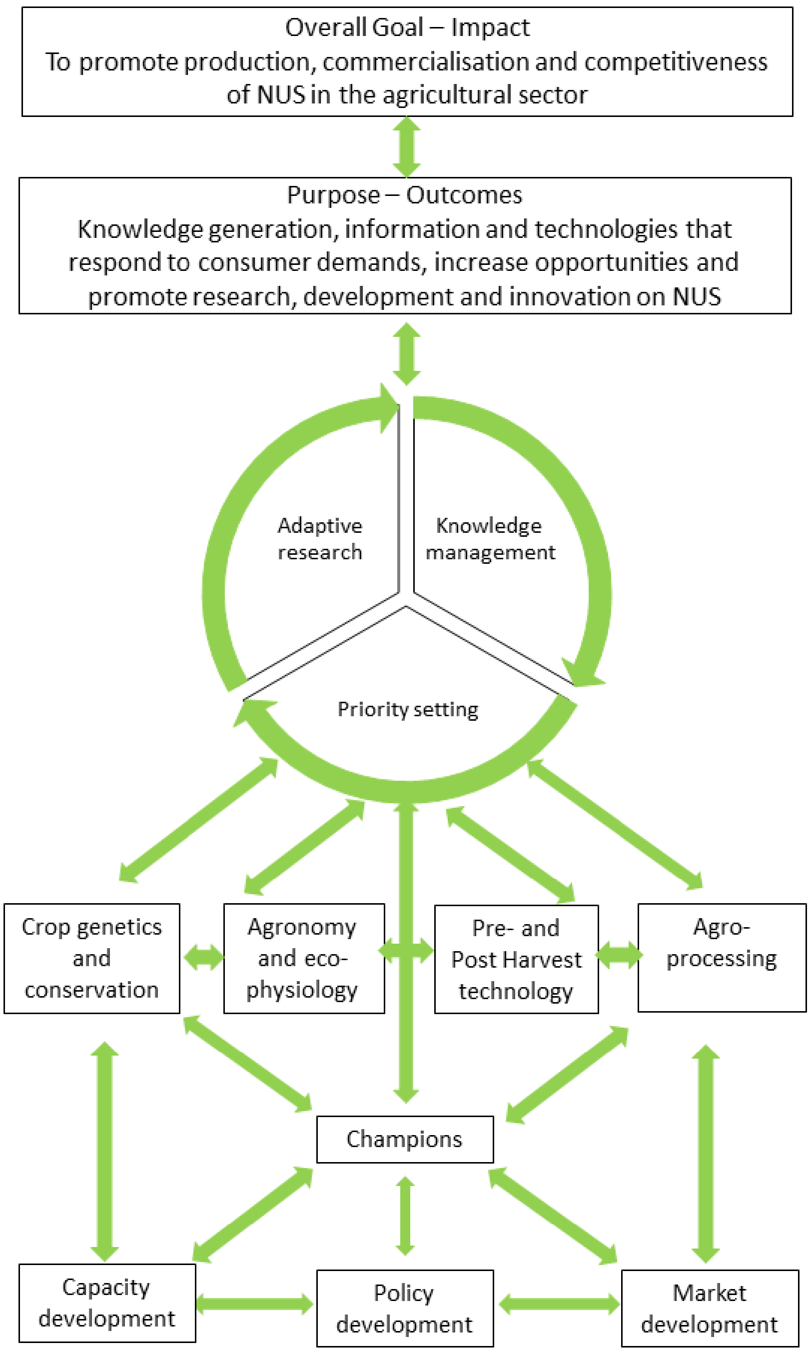

Figure 3.1: Schematic representation for research, development and innovation strategy for promoting underutilised crops in South Africa.

Figure 3.2: Innovation cycle for the Water Research Commission: a diagrammatic representation of adaptive research. (Source: Backeberg, 2014).

3.3.2.2 Knowledge management

It is increasingly recognised that promoting NUS could be enhanced by incorporating knowledge from multiple sources and using a variety of methods at different scales, including the perspectives of researchers, smallholder farmers and other stakeholders. Indigenous communities have been identified as the main custodians of knowledge regarding NUS. Much knowledge pertaining to the utilisation and intrinsic value associated with NUS remains hidden in the indigenous knowledge (IK) of these communities. Incorporating IK in research and development of NUS would help to steer away from top-down prescriptive development strategies Appropriate knowledge management mechanisms are therefore required to more efficiently harness these different sources of knowledge and facilitate their broader adoption, promotion, dissemination and application (Ison and Russell, 2007).

Currently, major crops are well endowed with coherent knowledge (scientific and indigenous) and this has contributed to their status. Contrary to this, many underutilised crops have neither the body of work, nor comprehensive research concerning how such a body of knowledge could or should be funded, assembled and put to work in raising the status of underutilised crops (Mabhaudhi et al., 2016). In addition, publicly available geo-referenced data is a powerful starting point for studies on NUS agro-ecological potential and adaptive capacity which in turn are useful for planning their further development. Knowledge is an essential resource for establishing competitive and comparative advantages for NUS in modern day agriculture. Therefore, its management by stakeholders should attempt to understand processes that lead to knowledge identification, generation, deployment, and efficient utilisation. These processes together define knowledge management.

Knowledge management is a discipline and a process that promotes an integrated approach to identifying, capturing, evaluating, retrieving, and sharing information. The process of knowledge management can also be used to simplify the complexity of documenting and sharing knowledge regarding NUS among people, strategies, methods, and technologies. Knowledge management can help to identify knowledge gaps and research priorities pertaining to NUS; improving the overall focus of the draft strategy. The definition of 'knowledge' itself is an on-going process (Berkes et al., 2000; Moller et al., 2004) with different relevance and perspectives to its users and is an important aspect within the draft strategy for NUS. This in itself is in line with the adaptive capacity of the draft strategy.

A large proportion of knowledge regarding NUS remains anecdotal and in the form of IK. Due to lack of proper documentation and validation, IK is often side-lined during the formulation of research objectives policies and strategies. The integration of IK and scientific knowledge and the promotion of participatory action research should underpin the knowledge management strategy and allow for continuous, dynamic, appraisal of RDI priorities. This will, in turn, ensure that RDI for NUS remains relevant to the end users' needs while at the same time contributing to national development agendas. As a starting step to knowledge management, available information on underutilised crops should be documented (*cf.* **Appendix 1**) and archived in a central database (*cf.* **Appendix 2**). Establishing a database for underutilised crops will help to (i) address the scattered nature of existing research outputs, and (ii) assist with identification of research gaps.

3.3.2.3 Priority setting

Research, development and innovation that focusses on underutilised crops is currently under-developed. As a result, the scale and complexity of focus areas is large making it challenging to develop an articulated draft strategy. It is widely recognised that priority setting is a critical step for any efficient and coherent strategic plan. Simply put a "priority" is a fact or condition that is more important than another. Within the context of this draft strategy, priority setting can be defined as a process of identifying activities that offer the best value and prospects of success for RDI for NUS. Therefore, priority setting for this draft strategy aims to appraise and harmonise RDI activities that will allow for the mainstreaming of NUS into current farming and cropping systems. Through priority setting, it is envisaged that the specific goals of the strategy can be more focused while at the same time increasing efficiency and accountability of decision making processes. Moreover, it is also envisioned that it will assist with the formulation of specific policies for NUS, strengthen investment and encourage equitable resource allocation for RDI. The review of the status of NUS indicated that there was scant and scattered information on NUS in South Africa that focussed on broad range of crops at the start-up point of the value chain. Thus, a major focus of the proposed strategy is to consolidate gains already made, establish new priorities that cater for specific underutilised crops with potential and ensure that future research targets all points of the value chain.

For NUS, a paradox exists regarding which, or whose, values should guide priority setting decisions and how these values should inform the decisions. Different methods have been used to formulate priority settings across different economic sectors and these include normative, empirical and research approaches. For instance, normative approaches are necessary because they help identify key values that clarify choices. On their own, these methods are insufficient because different approaches lead to different conclusions and there is no consensus about which ones have more value. As a result, they are too abstract to be directly used in actual decision making. On the other hand, empirical approaches are necessary because they help to identify what is being done and what can be done but are insufficient as they cannot identify what should be done. They have also been described as being rigid as they do not always consider the characteristics and limitations of the operating environments. Research approaches have been shown to be rigorous in the analysis and capture of experiences. However, the relevance of information coming from research approaches should be supported with normative and empirical approaches. The draft strategy proposes an evidence-based constructive and practical process that also combines normative and empirical methods. In this way, priorities set will be more holistic, feasible and relevant to South Africa's socio-economic and bio-physical constraints.

Priority setting should allow for an all-inclusive consideration of activities that will promote the RDI of NUS within South Africa. Hence, the process of priority setting should (i) be consistent with the research value chain (*cf.* **Section 1.5.1**), (ii) permit continuous monitoring, evaluation and assessment to allow for an adaptive process, and (iii) reflect the needs of all stakeholders along involved in the value chain. These attributes are consistent with the six-step priority setting process outlined in Figure 3.3 and the development of an adaptive strategy for NUS. It is also consistent with the WRC's innovation cycle (Figure 3.2). with regards to the draft strategy, in the initial phase, prevailing environments were analysed so as to identify gaps and opportunities within the RDI strategic plan for NUS. This was followed by the identification of priorities for RDI of NUS along the value chain. As part of the adaptive strategy, these should be complimented by a monitoring and evaluation framework.

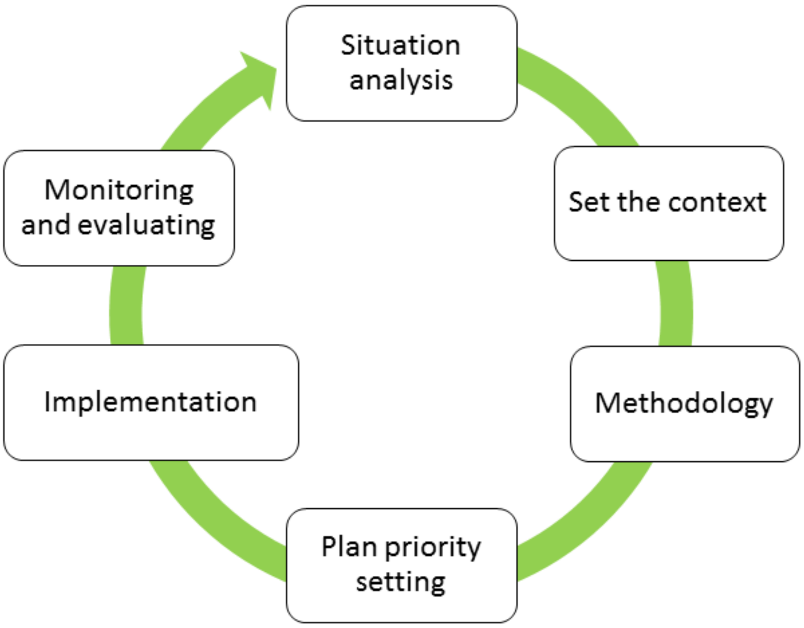

Figure 3.3: Process of priority setting for research, development and innovation strategic plan for neglected and underutilised crops in South Africa.

3.3.3 Principle Elements and Activities of the Draft Strategy

3.3.3.1 Crop improvement, genetics, and conservation

Neglected and underutilised species constitute 'within-species' diversity and provide resilience and local adaptation in traditional farming systems. They constitute a nutrient dense and diverse subset of food crops and present an opportunity to improve food and nutrition security in rural communities. As part of crop wild relatives (CWR), they provide beneficial traits to major crops, such as pest and disease resistance, and drought and heat tolerance. Gene sequencing and conservation of NUS and their CWR is thus a priority for their future development. In this regard, the following is proposed:

(a) Short to medium term – Crop improvement and genetics

Although, NUS possess many beneficial traits, they are generally low yielding which makes them unattractive to farmers and developmental agents. For instance, while amaranth had better nutritional value than spinach, its overall yield was less than that of spinach (Nyathi et al., 2012). A similar narrative has been given when bambara groundnuts was compared with dry beans, and sorghum with maize. This has significant impact on the successful commercialisation of these crops as the current low yields would not be viable to support their meaningful participation in mainstream agriculture. Increasing yield potential in major crops has largely been attributed to aggressive breeding and biotechnology programmes. Thus, there is also a need to employ such techniques to improve yield potential of NUS.

Conventional breeding, biotechnology and crop genetics are a key area of research that should be used to improve yields of underutilised crops. Plant genomics provide breeders with a new set of tools and techniques that allow the study of the whole genome to accelerate breeding efforts. We could use different biotechnology techniques developed for the sequencing of major crops and translate them for underutilised crops improvement. These methods include (i) developing SSR markers, (ii) conversion of multi-locus SNP markers to a single locus format, (iii) translating resources to assist breeding in underutilised crops, and (iv) generating pseudo-physical maps. Plant genomics could also be used to reveal new landscapes for NUS across different agro-ecological zones within South Africa and across the region. In addition, genetic sequencing will aid in identifying genes that confer beneficial traits that could be used for crop improvement of other species.

(b) Medium to long term – Bio-resource conservation of NUS

The conservation of genetic diversity of underutilised crops is key to the sustainable exploitation of NUS with regards to food and nutrition security and rural development. As such, a key element of this strategy is securing the resource base of underutilised crops to ensure that smallholder farmers and breeders have sustainable access to material.

i. Community seed banks are examples of on-farm management of local crop diversity. They allow for both natural and human selections to continually be part of genetic improvements. Community seed banks should be established, and in cases where they already exist, they should be strengthened to conserve, restore, revitalise, strengthen and improve seed systems of underutilised crops. The control and maintenance of these seed banks should solely be in the hands of local farmers who directly benefit from the seed. This will strengthen commitment and farmer participation with regards to conservation and sustainable use of genetic resources.

ii. Update and consolidate seed collections of indigenous crops in South Africa's national gene bank established by the National Plant Genetic Resource Centre of South Africa (NPGRC). The NPGRC includes mostly agricultural crops focusing on traditional NUS. A total of 44 species have been banked out of a possible 103 edible indigenous species that were collected by the Millennium Seed Bank project coordinated by SANBI in partnership with the Royal Botanic Gardens Kew.

3.4 POLICY

3.4.1 Alignment with Existing Policies

Underutilised crops are nutrient dense and provide an opportunity to improve access to nutritious food choices. Their ability to adapt to harsh conditions suggests that they can be used to champion agriculture for smallholder farmers residing in low potential environments. In addition, their vast genetic pool presents an important sub-set of agro-biodiversity; therefore, supporting landscape diversity in marginal cropping systems. The fact that their value chains are currently poorly developed creates opportunities to develop new value chains which, in turn, could create new employment opportunities and promote autonomous pathways out of poverty. Importantly, the significant role played by women in the conservation of NUS, which is recognised by the draft strategy, offers opportunities for gender empowerment through their involvement in the new value chains. Youth participation in such value chains would also contribute to addressing the poverty-unemployment-inequality nexus that is prioritised by the National Development Plan.

Implementation of the draft strategy for NUS can only be successfully if it is supported by, associated with and aligned to international, regional and national policies. Overall, the vision of the draft strategy has strong linkages with Sustainable Development Goals (SDGs) 1, 2, 3, 8 and 15. It also speaks to the Regional Indicative Strategic Development Plan (RISDP) (SADC, 2015), a guiding framework for the Regional Integration agenda for Southern African Development Community (SADC) for regional integration and poverty eradication; sustainable food security; and human and social development as priority intervention areas. The draft strategy is also consistent with South Africa's National Development Plan (NDP) - Vision 2030 (National Planning Commission, 2013), the 2015 Nine Point Plan, the New Growth Path and Outcomes 4, 7 and 10 of the Medium Strategic Framework which guide macroeconomic conditions that supports creation of employment opportunities, rural development and environmental conservation.

In addition, the draft strategy for NUS is also aligned to key national policies such as: The Integrated Growth and Development Planning (IGDP) (2010); National Department of Agriculture, Forestry and Fisheries (DAFF) Strategic Plan for 2016 – 2020; National Food Security Production Programme; and the National Policy on Food and Nutrition Security (2014). All these policies emphasise on the need to improve smallholders' participation in mainstream agriculture and the use of sustainable agricultural techniques for improved household food and nutrition security. The draft strategy is also consistent with the WRC's programme for sustainable water-based agriculture in rural areas as well the WRC's Knowledge Tree which seeks to achieve (i) transformation and redress, (ii) sustainable development solutions, (iii) empowerment of communities, (iv) inform policy and decision making, (v) capacity development, and (vi) new products developments for economic development.

3.4.2 Gaps in Existing Policies

The appraisal of NUS within mainstream agriculture requires that the current institutional environment recognises the opportunities that NUS offer for rural economic development. There is a need for a policy framework that (i) encourages stable and supportive macro- and micro-economic and regulatory environment for NUS, (ii) promote capacity development through appropriate skills development and educational systems, (iii) provide sufficient and reliable infrastructure, and (iv) provide adequate support for various forms of technology efforts within the value chain for NUS. This will encourage further support and involvement of stakeholders in the RDI of NUS and strengthen their relevance to current developmental initiatives within South Africa and the region. Furthermore, it allows for focusing and fine tuning of developmental goals and objectives, and identification of implementation gaps.

Such policy gaps could be addressed through updating and/strengthening existing policies so that they can be explicit on the role of South Africa's agro-biodiversity – underutilised crops. For example, the strategic grain reserves system which currently only prioritises maize and wheat, could be revised so that there is inclusion of a broader set of crops along the mentioned categories of cereals, legumes, root and tuber crops as well as vegetable crops. Such inclusion would also address dietary diversity through the formal recognition of the broader set of crops. Another example, would be to ensure that cross cutting issues such as the water-energy-food nexus, poverty-unemployment-inequality nexus, and water-food-nutrition-health nexus are mainstreamed into new policies that are currently being developed. Through such mainstreaming, underutilised crops could be more widely recognised for the different roles that they can also play.

3.5 CHAMPIONS

It is important to note that while the support of policy is critical to success of RDI for NUS, that alone cannot be taken to translate to success. Even the draft strategy, alone, cannot be instrumental in changing the existing paradigms for underutilised crops. There is a need to identify and support researchers and/or institutions that have shown a demonstrated track record and commitment to advancing the status of underutilised crops in South Africa. In this regard, the draft agenda places emphasis on the role of 'champions' in supporting the draft strategy and involvement in developing future research priorities.

Another consideration could be to support the establishment of a new institution or centre dedicated to driving research on underutilised crops. While this may sound ambitious, this option may offer advantages in terms of (i) nurturing capacity needed for underutilised crops RDI, (ii) coordinating the implementation of the draft strategy through, (iii) establishing national, regional and international partnerships, and (iv) attracting research funding to drive implementation of the strategy. Importantly, the establishment of such a centre would create continuity which often is the primary challenge in the case of 'champions'.

3.6 CONCLUSION

The draft agenda recognises the past and present status of underutilised crops in South Africa. While in the past underutilised crops have played a key role in securing the food and nutrition security, their present status shows a story of neglect and relegation to the peripheries of mainstream agriculture. The draft strategy acknowledges that several underutilised crops hold potential for addressing pressing national challenges such as the poverty-unemployment-inequality and water-food-nutrition-health nexus. It proposes that, in order propel underutilised crops from the peripheries of agriculture and into mainstream agriculture, there is a need for future research to prioritise those underutilised crops that show the best prospects for success. Particular attention should be given to those underutilised crops that are drought and heat stress tolerant, and nutrient dense. To this end, the draft strategy proposes a list of thirteen (13) priority underutilised crops split into categories of cereals, legumes, root and tuber crops, as well as traditional vegetable crops.

Future research, development and innovation for underutilised crops should focus on supporting and developing value chains for the identified priority underutilised crops. This will lead to the development of new value chains and open new opportunities for employment creation and poverty alleviation in rural areas. To this end, the draft strategy places emphasis on the meaningful participation of previously disadvantaged communities, women and youths through participatory action research and formulation of priorities. Their inclusion in the research, development and innovation strategy and subsequent value chains will open up new opportunities for them to participate in the mainstream economy. This supports the role of agriculture in supporting rural economic development.

There is a need for adaptive research and knowledge management to continuously inform new priorities for underutilised crops research, development and innovation. This will allow the draft strategy to continuously evolve and be capable to meet changing needs and demands in the global, regional and national landscapes. The draft strategy recognises that such knowledge management should promote the integration of scientific and indigenous knowledge. The draft strategy recommends that knowledge management should include the development of a database for archiving past, present and future research on underutilised crops in South Africa. This will go some way in addressing the scattered nature of existing research outputs and also assist in consolidating existing knowledge on underutilised crops.

The draft strategy recognises the role that major crops continue to play in the food and nutrition security of South Africans. This role can never be undermined and this draft strategy does not in any way seek to discount the contribution of major crops. However, the draft strategy recognises that complex challenges such as population growth, increasing water scarcity and climate change and variability pose an urgent threat to the capacity of major crops to continue to ensure food and nutrition security, especially in marginal agricultural production areas. The draft strategy therefore proposes that priority underutilised crops be promoted as alternatives, especially in marginal production areas where they may have competitive and comparative advantages due to their tolerance to drought and heat stress.

Lastly, champions, in the form of researchers and/or institutions are needed to support future research, development and innovation of underutilised crops in South Africa. Resources permitting, the draft strategy makes a strong recommendation for supporting a centre dedicated to the support and promotion of underutilised crops. This would ensure continuity and coordination of any strategy as well as place South Africa as a regional and global leader in underutilised crops' research, development and innovation.

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APPENDICES

Appendix 1: Resource Identification Sheet

Please provide the information in the grey areas for each resource and send file as attachment

1. Name/title of the resource:	
2. Authors	
3. Corresponding Author	
4. Institution	

5. What is the nature of the resource? (check column 1)

	Nature	Example
	Single resource	Document
	Journal Article	
	Collection	Series/set of documents
	Corporate website	
	Blog	
	Social media	FB, Twitter, forum ...
	Multimedia	Video, audio ...

6. Is it available online?

	Yes: Provide the link to the resource:	
	No: Provide name and email of contact person:	

7. Specify the focus of the resource?

Crop?	
Research area?	
Theme?	

8. Specify the status of the resource:

	Static (not anymore maintained)
	Dynamic (content still being added and maintained)

9. For whom is the resource?

Intended user group?

	Researchers		Extension		Farmers	**Other**	

Scope?

	Institutional		National		International	**Other**	

10. What about the copyrights and need for special permission?

Appendix 2: Crop Data Sheet

Crop name, *Scientific Name*
TAXONOMY AND NOMENCLATURE Optional (may be relevant for some species that have a confused history)
Provide scientific names and taxonomy, and origins of the crop
CROP MORPHOLOGY
Provide a description of crop morphology
DISTRIBUTION
Summary information on native, exotic, wild and cultivated distributions, including area of origin if known
BOTANY AND ECOLOGY
Provide details of crop growth stages and requirements for growth
DROUGHT TOLERANCE
Description of drought tolerance mechanisms
CLIMATE CHANGE ADAPTATION
Strategies for climate change adaptation
GENETIC RESOURCES AND BREEDING
Number of available accessions in gene banks and collections
PESTS
Common pests, weeds, and their control
PRODUCTION AND TRADE
Include information on production and area under production if available. Also include information on yields achieved and under what conditions
IMPORTANCE AND UTILISATION
Describe major uses and products
NUTRITIONAL VALUE
Describe the nutrient content of the edible plant parts
OPPORTUNITIES
Are there any meaningful opportunities for developing this crop?
PRIMARY SOURCES
Main sources of literature used

Appendix 3: Completed and On-Going Research Activities Funded by the WRC

Research theme	**Project titles**	**Authors/ YEARS**
Drought and heat tolerance	Molecular and physiological approach to drought and heat tolerance for selected crops	de Ronde et al. (1999)
	Screening of Cowpea, Bambara Groundnut and Amaranthus germplasm for drought tolerance	Spreeth et al. (2004)
	Symposium on water use and agronomy of traditional crops	2009
	Water use and drought tolerance of selected traditional crops	Modi and Mabhaudhi (2013)
Water Use and Nutritional Value of Food Crops	Symposium on the nutritional value and water use of indigenous crops (2006)	WRC (2006)
	Water SA special issue (2007)	http://www.wrc.org.za/Pages/KH_WaterSA.aspx?dt=5&L0=1&L1=4&start=61
	Nutritional value and water use of African leafy vegetables for improved livelihoods (	Oelofse and Averbeke (2012)
	Production guidelines for African leafy vegetables	Jansen van Rensburg et al. (2012)
	Press release, articles in Water Wheel and Farmer's Weekly (2013)	http://www.wrc.org.za/Pages/KH_WaterWheel.aspx?dt=4& http://www.farmersweekly.co.za/
Nutritional Water Productivity	Nutritional status of South Africans: Links to agriculture and water	Wenhold and Faber (2008)
	Scoping study on water use and nutrient content of crop and animal food products for improved household food security	Wenhold et al. (2012)
	Press release, articles in Water Wheel and Farmer's Weekly (2013)	http://www.wrc.org.za/Pages/KH_WaterWheel.aspx?dt=4& http://www.farmersweekly.co.za/
Ongoing and Future Research	Water use and nutrition of indigenous vegetables	2011 – 2016
	Potential of current rain-fed and irrigated production of food crops to meet all year round nutritional	

	requirements of rural poor people (2012)	
	Water use of indigenous grain and legume food crops (2013)	2013 – 2017
	Water use of crops and nutritional water productivity for food production, nutrition and health in poor rural communities	2015 – 2020
	Workshop to determine priorities for further multi-disciplinary research in crop, soil, food, nutrition, social and economic disciplines	Yearly
	Developing a research agenda for promoting underutilised, indigenous and traditional crops	2016
	Water use for food and nutrition security at the start-up stage of food value chains	2017 – 2021
	Water use of indigenous fruit tree crops	2018 – 2022
	Rainwater harvesting and conservation practices for cultivation of indigenous crops as part of the crop choice and crop rotation in homestead food gardens and communal croplands	2018 – 2022
	Developing a guideline for rain-fed production of underutilised indigenous crops and estimating water use of indigenous crops based on available models within selected bio-climatic regions of South Africa	2018 – 2022

Appendix 4: Supplementary information: preliminary data set of priority underutilised crop species in South Africa

CEREALS

Sorghum (*Sorghum bicolor*)

TAXONOMY AND NOMENCLATURE
Sorghum is a member of the family Poaceae and the tribe Andropogoneae. *S. bicolor* - diploid (2n=20) all annual and domesticated types, including stabilized weedy derivatives such as Sudangrass.
CROP MORPHOLOGY
Root system Sorghum has a primary and secondary root system. The primary roots are those which appear first from the germinating seed. The primary roots provide the seedling with water and nutrients from the soil. Primary roots have a limited growth and their functions are soon taken over by the secondary roots. Secondary roots develop from nodes below the soil surface. The permanent root system branches freely, both laterally and downwards into the soil. If no soil impediments occur, roots can reach a lateral distribution of 1 m and a depth of up to 2 m early in the life of the plant. The roots are finer and branch approximately twice as much as roots from maize plants. **Leaves** Sorghum leaves are typically green, glasslike and flat and have a leaf area smaller than that of maize. The leaf blade is long, narrow and pointed. Young leaves have upright leaf blades, however, the blades tend to bend downwards as the leaves mature. A unique feature of sorghum leaves is the rows of motor cells along the midrib on the upper surface of the leaf. These cells can roll up leaves rapidly during soil moisture deficit. Leaves are covered by a thin wax layer and develop opposite one another on either side of the stem. Number of leaves, vary from eight to 22 leaves depending on environmental conditions. **Stem** Stems are solid, dry, succulent and sweet. Under favourable conditions more internodes develop, together with leaves, producing a longer stem. The stem consists of internodes and nodes. Stem diameter varies between 5 mm and 30 mm. The internodes are covered by a thick waxy layer, giving it a blue-white colour. The waxy layer reduces transpiration and increases the drought tolerance of the plants. The root band of nodes below or just above the soil surface develops prop roots. The growth bud develops lateral shoots. Sometimes the growth buds higher up the stem may also develop lateral shoots.

Inflorescence (panicle)

The inflorescence of sorghum is a compact panicle. The shape and colour of the panicle varies between cultivars. Heads are carried on a main stem or peduncle with primary and secondary branches on which the florets are borne. The peduncle is usually straight and its length varies from 75 to 500 mm. Each panicle contains from 800 to 3 000 kernels, which are usually partly enclosed by glumes. Glume colour may be black, red, brown or tan. The flowers of sorghum open during the night or early morning. Those at the top of the panicle open first and it takes approximately 6 to 9 days for the entire panicle to flower.

Seed

Seed are oval to round and the colour may be red, white, yellow, brown or shades. They are partially enclosed by glumes, which are removed during threshing and/or harvesting. The sorghum grain consists of the testa, embryo and endosperm.

DISTRIBUTION

Sorghum is the 5th most important grain crop after wheat, maize, rice and barley. It is indigenous to Africa.

BOTANY AND ECOLOGY

Soil requirements

Sorghum grows under marginal soils even with high clay content. Sandy soils that lack a heavy textured subsoil are not ideal. Sorghum is tolerant of alkaline salts and can be cultivated on soils with a pH (KCl) between 5.5 and 8.5. Sorghum can better tolerate short periods of water logging.

Climatic requirements

Sorghum is a tropical crop, which requires high temperatures for good germination and growth. The minimum temperature for germination varies from 7 - 10°C. At a temperature of 15°C, 80% of seed germinate within 10 - 12 days. The best time to plant is when there is sufficient water in the soil and the soil temperature is 15°C or higher at a depth of 10 cm. Optimum temperature for growth and development of sorghum is 27 - 30°C. Flower initiation and the development of flower primordia are delayed with increased day and night temperatures. Temperatures below freezing are detrimental to sorghum and may kill the plant. At an age of one to three weeks, plants may recover if exposed to a temperature of 5°C below the freezing point, but at 7°C below freezing, plants are killed. Plants older than three weeks are less tolerant to low temperatures and may be killed at 0°C.

Day length

Sorghum is a short-day plant. Optimum photoperiod is 10 - 11 hrs and induces flower formation. Photoperiods longer than 11 - 12 hours stimulate vegetative growth. Sorghum plants are most sensitive to photoperiod during flower initiation.

Water requirements

Sorghum is produced in South Africa on a wide range of soils, and under fluctuating rainfall conditions of approximately 400 mm in the drier western parts to about 800 mm in the wetter eastern parts.

DROUGHT TOLERANCE

Sorghum is able to tolerate drought better than most other grain crops and can be attributed to an exceptionally well developed and finely branched root system, which is very efficient in the absorption of water. It also has a small leaf area per plant, which limits transpiration; The leaves fold up more efficiently during warm, dry conditions than that of maize. It has high osmotic adjustment, waxy bloom substance in leaves and stem and better adjustment in leaf angle during water deficits.

CLIMATE CHANGE ADAPTATION

With increasing heat stress events and reduced summer rainfall predicted sorghum drought and heat stress properties make it a potential climate adaptation crop choice.

GENETIC RESOURCES AND BREEDING

Sorghum can be improved as a self-pollinating crop, or using recurrent selection procedures for cross-pollinating crops, through the manipulation of male sterility systems. ICRISAT (CGIAR centre) has a mandate for sorghum improvement. The main target areas for their sorghum improvement effort are India, West and southern Africa.

CROP PROTECTION

Weed control

Weed control during the first 6 - 8 weeks after planting is crucial, as weeds compete vigorously with the crop for nutrients and water during this period. The root parasite *Striga asiatia* (L.) Kuntze or witchweed (rooiblom) can damage the crop and mainly occurs under low-input farming conditions. The parasitic plants are single stemmed with bright red flowers. Most of the damage is done before the parasite emerges from the soil. The symptoms include leaf wilt, leaf roll, and leaf scorch, even though the soil may have sufficient water. The tiny seeds are disseminated by wind, water and animals, and remain viable in the soil for 15 - 20 years. Rotation with cotton, groundnut, cowpea and pigeon pea will reduce the incidence of Striga. Hand pulling the plants before flowering could be used. Weeds can be removed mechanically, using manual labour or implements. Ploughing during winter or early spring is an effective method of controlling weeds. Chemicals formulated as liquids, granules or gasses can be applied to kill germinating, growing weeds or seeds. Control of nut-grass with pre-emergence herbicides is not effective when applied after emergence. It is important to cultivate fields before applying herbicides. Wild sorghum in sorghum fields can only be controlled mechanically or by hand hoeing.

Pest control

Integrated pest management Integrated pest management is a system whereby various methods are applied to protect the crop by suppressing insect populations and limiting damage. These measures include the following: chemical control, biological control, plant resistance and cultural control.

Preventative control

For both Chilo borer and the maize stem borer, the economic threshold level of 10 % infested plants in a sorghum field applies. This value implies that there are sufficient larvae in the field to cause economic damage and that chemical control should therefore be applied. For bollworm on sorghum the economic threshold level is when on average two larvae occur per panicle and only then spraying should take place. In the case of aphids, timely control is very important, however, spraying at first indication of an infestation is not necessary. An indication that the aphid population is nearing economically important levels, is when virtually all plants are infested. Spraying at this stage will ensure that the crop is free of aphids for the greater part of the most sensitive period, namely grain filling.

Cultural methods

These practices include soil cultivation during winter, eradicating volunteer plants, cultivar choice and adapting planting times.

Biological control

Natural control of pests occurs continually in fields where natural enemies attack all the life-stages of insect pests. Aphids and diapause larvae of stem borers are particularly vulnerable to natural enemies. The complex of natural enemies can be protected to a certain extent by using insecticides which are more environmentally friendly and which are not highly poisonous to non-target organisms.

PRODUCTION AND TRADE

Average sorghum yield on smallholder farms is estimated at 0.8 t ha^{-1}. In the Limpopo Province, sorghum is grown on at least 25 342 ha. Sorghum is also produced in other provinces such as Mpumalanga, North West, Northern Cape, Eastern Cape, KwaZulu-Natal and Free State. Statistics from these provinces are not available. South African commercial farmers, located mostly in the Free State, produce on average 300 000 ton on 150 000 ha.

IMPORTANCE AND UTILISATION

Sorghum grain is used for stock feed and It provides for human food. Sweet sorghum has sweet juicy stems which may be used for forage and silage or to produce syrup. The juicy stems are often chewed as a snack by humans in southern Africa. Also used for ethanol production. Sweet sorghum appears to be suitable for the production of alcohol. Sweet sorghum has the potential for fuel and alcohol production. Sweet sorghum bagasse is a suitable source of paper pulp The pulp is used to manufacture kraft paper, newsprint and fibre boards

NUTRITIONAL VALUE

The whole sorghum grain consists of about 12% protein, 75% starch, 4% fat and 4% minerals. The rest of the grain is fibre. Sorghum also supplies a lot of minerals – one cupful contains 55% of the recommended daily allowance (RDA) of phosphorus, 47% of iron, 19% of potassium, 5% of calcium and even some magnesium and zinc. A cup of sorghum contains – 30% for thiamine, 28% for niacin and 16% for riboflavin. Sorghum is low in sodium and saturated fat and completely cholesterol free.
PRIMARY SOURCES
• http://www.arc.agric.za • http://www.nda.agric.za • http://repository.up.ac.za

Teff (*Eragrostis tef*)

TAXONOMY AND NOMENCLATURE
Teff belongs to the Poaceae or Grass family. It is closely related to finger millet (*Eleusine coracana* Gaerth.) as both are in the subfamily Chloridoideae. The genus *Eragrostis* comprises about 350 species from which only teff is cultivated for human consumption. Teff is a C4 plant.
CROP MORPHOLOGY
Teff is a C4, self-pollinated, chasmogamous annual cereal. It has a fibrous root system with mostly erect stems, although some cultivars are bending or elbowing types. The sheaths of tef are smooth, glabrous, open and distinctly shorter than the internodes. Its ligule is very short and ciliated while its lamina is slender, narrow and nearly linear with elongated acute tips. It has a panicle type of inflorescence showing different forms – from loose to compact, the latter appearing like a spike. Its spikelets have 2-12 florets. Each floret has a lemma, palea, three stamens, an ovary and mostly two, in exceptional cases three, feathery stigmas. The caryopsis is 0.9-1.7 mm in length, and 0.7-1.0 mm in diameter, which is very small, and its colour varies from white to dark brown. Fertilisation was found to occur in the basal floret of a spikelet when that floret was at the base of the flag leaf blade. The maturation of flowers is basipetal on the panicle and on each branch, while acropetal on the spikelet basis. The flowers of teff are hermaphroditic with both the stamens and pistils being found in the same floret. Florets in each spikelet consist of three anthers, two stigmas and two lodicules that assist in flower opening. Teff is a self-pollinated chasmogamous plant.
DISTRIBUTION
Ethiopia is the origin and centre of diversity for tef. The crop is widely cultivated in Ethiopia and neighbouring countries.
BOTANY AND ECOLOGY
Teff is adapted to a wide range of environments and is presently cultivated under diverse agro climatic conditions. It can be grown from sea level up to 2800 m a.s.l, under various rainfall, temperature and soil regimes. Grows well in areas with annual rainfall of 750 - 850 mm, growing season rainfall of 450 - 550 mm and a temperature range of 10°C - 27°C. Teff suffers less from diseases and gives better grain yield when grown on Vertisols rather than on Andosols. Seedbed preparation is important to overcome the problem of poor stand establishment, soil crusting and cracking when dry and water logging during wet periods. Teff is a neutral day plant and is sensitive to day length. Flowering is greatly affected by photoperiod; flowers remain open for longer periods, most of the anthers don't produce pollen grains, and seed set is low.
DROUGHT TOLERANCE
Altered physiological processes, leaf architecture and cell wall chemistry were associated with teff drought tolerance mechanisms.
CLIMATE CHANGE ADAPTATION
The ability of the crop to grow in diverse environments and its nutritional value makes it an extremely important crop in improving the resilience, income and food security, especially under climate change.

GENETIC RESOURCES AND BREEDING

The Plant Genetic Resources Centre of Ethiopia (PGRC/E), now called the Biodiversity Institute, is actively engaged in collecting, conservation and characterisation of tef.

CROP PROTECTION

Weeding

It is best to start with a weed-free and clean field that has been ploughed in the appropriate season and frequently enough to kill the weeds. The work should also start with clean teff seeds that are free of weed seeds. Hand-weeding once at early tillering stage (25 - 30 days after emergence) is ideal and adequate, if the weed population is low. However, if the infestation is high, a second weeding should be done at the stem-elongation stage. On the other hand, hand-weeding after heading is not recommended, since it may result in heavy damage to the plants. Weed competition causes about 52% crop losses, but with hand-weeding.

Diseases

Diseases are not a serious problem. In the major teff-growing areas of Ethiopia teff suffers less from diseases than most other cereal crops in the major production areas of Ethiopia.

PRODUCTION AND TRADE

In South Africa, tef is an underutilised crop with its crop wild relative *Eragostis curvula* cultivated as a pasture crop. The limited production is mainly associated with consumption by local Ethiopian and Eritrean populations.

IMPORTANCE AND UTILISATION

In Ethiopia, teff is traditionally grown as a cereal crop. The grain is ground to a flour which is mainly used for making a popular pancake-like local bread called injera and sometimes for making porridge. The grain is also used to make local alcoholic drinks, called tela and katikala. Teff straw, besides being the most appreciated feed for cattle, is also used to reinforce mud and plaster the walls of tukuls and local grain storage facilities called gotera. Teff grain, owing to its high mineral content, has started to be used in mixtures with soybean, chickpea and other grains in the baby food industry. Injera made from tef is traditionally consumed with wot, a sauce made of meat or ground pulses like lentil, faba bean, field pea, broad bean and chickpea. This indicates that the traditional way of consuming teff with wot, is wise, since the wot, supplements the lysine deficit in teff and provides a better balanced diet. In some regions of Ethiopia, e.g. Welo, women usually prepare injera by adding some fenugreek to teff to improve its baking quality. Because of this, the injera becomes softer and has a shiny appearance. Teff is predominantly grown in Ethiopia as a cereal crop and not as a forage crop.

However, when grown as a cereal, farmers highly value the straw of teff and it is stored and used as a very important source of animal feed, especially during the dry season. Farmers feed teff straw preferentially to lactating cows and working oxen. Cattle prefer teff straw to the straw of any other cereal and its price is higher than that of other cereals.

NUTRITIONAL VALUE

It has a starch content of approximately 73%, making teff a starchy cereal. This somewhat lower GI for teff than expected may be explained by its amylose content, lower starch damage, and the possible formation of amylose-lipid complexes that can hinder enzymatic access and thus starch

digestibility. The average crude protein content of teff is in the range of 8 - 11%. Teff grains are rich in unsaturated fatty acids, predominantly oleic acid (32.4%) and linoleic acids (23.8%). Teff has a higher iron, calcium and copper content than other common cereals. The zinc content of teff is also higher than that of sorghum and wheat.
OPPORTUNITIES
The ability of teff to tolerate and grow under waterlogged conditions is one of its advantages and a characteristic that makes it preferred by farmers. The other advantage of teff for farmers is its suitability for easy storage under local storage conditions, without incurring much loss. Teff does not incur any loss as a result of damage by any storage insect pests. Currently diseases are not a serious problem in teff production. Teff suffers less from diseases than most other cereal crops.
PRIMARY SOURCES
• Seyfu Ketema. 1997. Tef. Eragrostis tef (Zucc.) Trotter. Promoting the conservation and use of underutilized and neglected crops. 12. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy

LEGUMES

Bambara Groundnut (*Vigna subterranea*)

TAXONOMY AND NOMENCLATURE
Bambara groundnuts (*Vigna subterranea* (L.) Verdc), belongs to the family Leguminosae, subfamily Papilionoideae and genus Vigna. Both wild and cultivated species have 2n=2x=22 number of chromosomes. The crop was called various names, including: Mandubi d' Angola (Marcgrav de Liebstad, 1648), while Linnaeus in 1763 designated it as Plantarum, and then re-named it Glycine subterranea. In 1806, Du Petit-Thouars proposed the name *Voandzeia subterranea* [L.] Thouars. This name was popularly known and used by most researchers for a century. Botanical studies by Maréchal et al. (1978) revealed strong connections between Bambara groundnut and the genus Vigna. This was confirmed by Verdcourt (1980), who proposed a change of genus name to "*Vigna subterranea* [L.] Verdc."
CROP MORPHOLOGY
Bambara groundnut is a low flat annual with compound leaves of three leaflets. The plant can be categorized into bunch, semi–bunch and open cultivars on the basis of the ratio petiole length/ internode length or canopy diameter. The petioles are approximately 15 cm long, stiff and grooved and the base is green or purple in colour. Leaves and flower buds arise alternately at each node. After fertilisation the flower stem elongates. The sepal enlarges and the fruit develops above or just below the soil surface. The unripe pod is yellowish green with up to six pods while mature pods may be yellowish green or purple. The pods are round, wrinkled and while seeds are round, smooth and very hard.
DISTRIBUTION
In Africa bambara groundnut is the third most important legume after groundnut (*Arachis hypogea*) and cowpea. It is cultivated in rural areas from Senegal to the Ethiopian lowlands, as well as in South Africa and Madagascar.
BOTANY AND ECOLOGY
Bambara groundnut grows best in areas receiving 400 - 600 mm of annual rainfall with an average temperature of 25°C. Planting dates for bambara groundnut range from September to February. Recommended planting in sub-tropical and tropical regions is November. The crop does not tolerate water logging. It is grown mostly on flat ground but in wetter areas mounds or ridges are preferred. Best mounding times were shown to be seven weeks after planting. Bambara beans take 7 - 15 days to germinate. Flowering starts 30 - 35 days after sowing and may continue until the end of the plant life. It is a typical short-day plant. Vegetative growth takes place in spring and early summer and pods form only in late summer and autumn. Pod and seed development take place approximately 30 - 40 days after fertilisation. The fruit of bambara groundnut develops on or below the soil surface. The pod develops first. This takes up to 30 days after fertilisation. The seed develops during a further 10 days.

At maturity biomass ranges from 1 500 - 8 500 kg ha^{-1} while pod yield ranges from 300 - 3 000 kg ha^{-1}. Grain yield ranges from 400 - 4 000 kg ha^{-1} while haulm yield ranges from 2 500 - 8 000 kg ha^{-1}.

DROUGHT TOLERANCE

Bambara groundnut is widely regarded as drought tolerant due to its ability to maintain high tissue water potential under drought tolerance and drought avoidance mechanisms.

CLIMATE CHANGE ADAPTATION

Bambara groundnut (*Vigna subterannea* (L.) Verdc.) is very drought tolerant and is also known to possess good heat stress tolerance. Thus, it would be ideal for cultivation in areas that are projected to experience declining rainfall and increasing temperature i.e. hot and dry scenario. As a legume, it is also an ideal crop for intercropping with other hardy cereal crops such as sorghum and millets.

GENETIC RESOURCES & BREEDING

Bambara groundnut is primarily grown using landraces or farmers' varieties. Farmers grow local landraces from previous harvests, or buy from local markets, because there are no available improved varieties of the crop for small or large scale production. Initial collections and evaluations of Bambara groundnut landraces were carried out by the International Institute of Tropical Agriculture (>2000). In South Africa, there are approximately 300 accessions kept at the Agricultural Research Council – Grain Crops Institute, Institute for Veld and Forage Utilisation and Department of Agriculture.

CROP PROTECTION

Pests

The pests attacking bambara are fusarium wilt, leaf spot and root-knot nematode. These are triggered by rainy weather and light textured soils. Others are leafhoppers, *Hilda patruelis* and the larvae of *Diacrisia aculosa* and *Lamprosema indicata*. *Meloidogyne incognita* and *Meloidogyne javanica* are the most parasitic nematodes on bambara groundnut. The symptoms of nematode infestation include stunted growth, leaf chlorosis and yield losses. About 10 weeks after planting, the leaves turn yellow and the plants become stunted and die.

Diseases

Diseases include Peanut Clump Virus (PCV) which persists in soil even for several years as its fungal vector, *Polymyxa graminis*, is capable of producing highly resistant resting spores. PCV can be transmitted by planting seeds.

Weeds

Weed control is done mechanically or by hand. Care should be taken when weeding around the plant, especially at flowering as the flower stalks are fragile and may break with rough handling. There are no registered herbicides for bambara at the moment, but those registered for cowpea could be used for bambara groundnut.

PRODUCTION AND TRADE

The top five bambara groundnut producing countries in the world (in descending ranking order) are: Burkina Faso, Cameroon, Mali, Niger and Democratic Republic of Congo, together, producing just over 140 000 MT per annum.
IMPORTANCE AND UTILISATION
Bambara seeds can be eaten fresh when semi-ripe, as a pulse when dry and mature or can be ground into flour. The fresh pods are boiled with salt and pepper and eaten as a snack. Flour from Bambara groundnut in addition to being used to prepares cakes it is used in weaning food formulation. The seeds of bambara groundnut are also used to produce a paste which is used to prepare akara. Bambara groundnut seeds can be used to produce vegetable milk. The leaves of bambara groundnut are used as animal feed. The Luo tribe in Kenya explore the medicinal properties of bambara groundnut by using water from boiled grain to treat diarrhoea.
NUTRITION
Bambara groundnut possesses sufficient quantities of nutrients such as proteins, vitamins and minerals. Bambara groundnut seeds provide an important source of crude protein (up to 24%), carbohydrates (up to 63%) and fats (up to 6.5%). The crop also has a good balance of essential amino acids, and is rich in essential amino acids.
OPPORTUNITIES
Bambara groundnut has great opportunities towards food security, sustainability, income generation, product development, dietary diversification and animal feed.
PRIMARY SOURCES
• Azam Ali *et al*. (2001) • Mabhaudhi *et al*. (2013)

Cowpea (*Vigna unguiculata*)

TAXONOMY AND NOMENCLATURE
The Vigna genus belongs to the, Leguminosae family, and Papilionoideae subfamily. There are four species groups in this genus largely distributed throughout the world, including the group classified as *Vigna sinensis* (L) Savi. There are many classification of the forms of this group, according to the existing variations, some being considered as botanical varieties by some authors and subspecies by others. At present time, the most common classification is that one which recognizes this group as *Vigna unguiculata* (L.) Walp.
CROP MORPHOLOGY
Plants may be erect, trailing, climbing or bushy depending on variety. Under favourable conditions cowpea is indeterminate. **Root** Cowpea has a strong taproot and many spreading lateral roots in surface soil. **Leaves** The first pair of leaves is basic and opposite while the rest are arranged in an alternate patterns and are trifoliate. The leaves are usually dark green in colour and vary in size. Leaf petiole are 5 - 25 cm long depending on variety. Stems are smooth or slightly hairy ad may have a purplish colour. **Inflorescence** Flowers are arranged in racemose or intermediate inflorescences at the distal ends of 5 - 60 cm long peduncles. Flowers are borne in alternate pairs, with usually only two to a few flowers per inflorescence. Flowers are conspicuous, self-pollinating, borne on short pedicels and the corollas may be white, dirty yellow, pink, pale blue or purple in colour. **Fruit and seeds** Seeds vary considerably in size, shape and colour. In one pod you find between 8 - 20 seeds. Average grain ass for 100 seeds is 5 - 30 g. The testa may be smooth or wrinkled; white, green, buff, red, brown, black, speckled, blotched, eyed (hilum white, surrounded by a dark ring) or mottled in colour. Pods that vary in size, shape, colour and texture. They may be erect, crescent-shaped or coiled. Colour of pods is usually yellow when ripe, but may also be brown or purple in colour.
DISRTIBUTION

Cowpea is grown throughout the tropics and subtropics. Cowpea is believed to have originated from West Africa because both wild and cultivated species are found in the region. Its production has spread to Africa, Asia, South and Central America.

BOTANY AND ECOLOGY

Temperature

Cowpeas is a tropical legume that grows best during summer. The base temperature for germination is 8.5°C and for leaf growth 20°C. The optimum temperature for growth and development is around 30°C. The optimum sowing times are December to January. Early-sown crops tend to have elongated internodes, are less erect, more vegetative and have a lower yield than those sown at the optimum time. The presence of nodular bacteria specific to cowpea (Bradyrhizobium spp.), make it suitable for cultivation in the hot, marginal cropping areas of Southern Africa, as well as in the cooler, higher rainfall areas.

Water

Cowpea is a drought-tolerant crop. It can grow under rainfall ranging from 400 to 700 mm per annum which has to well-distributed for normal growth and development. Cowpeas are also have a great tolerance to waterlogging. Cowpeas utilise soil moisture efficiently and are more drought-tolerant than groundnuts, soya-beans and sunflowers. In high rainfall areas, cowpeas could be planted at a time to coincide with the peak period of rainfall during the vegetative phase or flowering stage so that pod-drying could take place during dry weather. Most sensitive stages to drought are flowering/podding stage. Drought response mechanisms include, limiting growth (especially leaf growth) and reducing leaf area by changing leaf orientation and closing the stomata. Flower and pod abscission during severe moisture stress also serves as a growth-restricting mechanism.

Soil requirements

Cowpeas are grown on a wide range of soils but grows best on sandy soils that don’t restrict root growth. Compared to other crops cowpeas can tolerate infertile and acid soils. Cowpeas are sensitive to cold soil and water logging. It requires a soil pH of between 5.6 - 6.0.

DROUGHT TOLERANCE

The deep root system of cowpea enables the crop to capture water from deep soil layers. Drought response mechanisms include, limiting growth (especially leaf growth) and reducing leaf area by changing leaf orientation and closing the stomata. Due to this, cowpea can maintain a high water potential under low soil moisture conditions.

CLIMATE CHANGE ADAPTATION

Cowpea’s drought and heat stress tolerance make it an ideal crop for fitting into areas that are projected to experience increasing temperatures and declining rainfall, i.e. hot and dry weather. As a legume, it is also an ideal crop for multicrop systems such as intercropping and soil water conservation strategies where it can provide ground cover as a live mulch.

GENETIC RESOURCES AND BREEDING

Cowpea is one of the Agricultural Research Council's mandate crops. Considerable progress has been made in developing improved genotypes suitable for the South African environment and market in the last three years and to replace old and pest-susceptible cultivars. More germplasm accessions are needed to increase genetic diversity of South Africa's cowpea genebank and develop more high-yielding genotypes with acceptable seed size and quality as well as disease resistance and drought tolerance. Significant progress has been made in breeding cowpea cultivars with different maturity groups (early and medium maturity), dual-purpose and fodder types.

CROP PROTECTION

Weed Control

Annual grasses and some broadleaf weeds can be controlled by a pre-sowing application of herbicide. Row crop cultivation may be necessary with cowpeas, depending on the weed pressure, soil conditions, and rainfall. Preplant tillage can assist greatly in reducing early weed pressure, and the use of cover crops. *Striga gesnerioides* and *Alectra spp*. are the principal parasitic weeds attacking cowpeas, particularly in the semiarid regions. The following three are the most common Striga species that are a pest to cowpea: S. *hermonthica, S. asiatica* and *S. gesnerioides*.

Control of Striga is difficult and time consuming. At present, chemical control is not recommended, as the chemicals are expensive, handling them is very difficult and no research results are available to support chemical treatment. Farmers are advised to improve soil fertility where this weed is a problem. Soil fertility has an effect on Striga infestation; more fertile soils are less infested with Striga. Use of manure and/or small quantities of fertiliser may reduce the infestation, when combined with weeding of plants before seed setting. Hand weeding of the infested areas before Striga sets seeds is the most important control method at present. Striga should be weeded out as soon as any flowering is observed, as the development of seeds takes only a few weeks. It may be necessary to weed the area twice in a season.

Pest

Cowpea attracts insect pests such as sucking bugs (Riptortus spp., Nezara viridula and Acantomia sp.), aphids (Aphis fabae, Aphis craccivora), blister beetle (Mylabris spp.) and pod borer (Maruca vitrata).

Control should only be considered where large infestations are threatening the crop or when viral infections have been observed. This is based on visual severity and stage of development. Several commercial pesticides are available to control aphids, of which the most effective are systemic pesticides. In some cases heavy rain may reduce the number of aphids, for example the black cowpea aphid, which is very exposed on the pods. Frequently, parasites and predators prevent the infestation from becoming established throughout a field. Hot temperatures (higher than 30°C) frequently inhibit build-up of large densities of aphids. If a few plants are seriously affected these can be pulled up and burnt or fed to livestock. Remove harvested plants from field as they are often hosts to aphids.

To control bruchids farmers often mix cowpea grains with ash. This method is still recommended as a cheap and safe control method. To be efficient, at least 5% ash should be used. Chemical control should be accompanied by sound technical knowhow. Farmers do not consider most beetles important pests unless there is a large number found on flowering crops. Handpicking of beetles is not frequent because most species are known to give blisters. To speed up handpicking, a basic homemade net could be used for catching the flying beetles.

Diseases

The most important disease of cowpea is stem rot caused by Phytophthora vignae. This disease frequently occurs in the wetter coastal and subcoastal areas, and on heavier soils which may become waterlogged. Bacterial blight (Xanthomonas vignicola) causes severe damage to cowpeas, while the most frequent virus disease encountered is aphid-borne mosaic virus (CabMV). Fusarium wilt, bacterial canker, Cercospora leaf spot, rust and powdery mildew. Cowpea is susceptible to nematodes and should not be planted consecutively on the same land.

PRODUCTION AND TRADE

A large producer of cowpeas is small-scale farmers under dryland farming conditions. There are no records with regard to the size of area under production and the quantities produced.

IMPORTANCE AND UTILISATION

Cowpea is used both as a vegetable and grain. The dried pulse may be cooked together with other vegetables to make a thick soup, or ground into a meal or paste, before preparation in a variety of ways. Similarly, fresh, immature pods may be boiled as a vegetable. Fresh leaves and growth points are often picked and consumed in the same way as spinach. Dried leaves are preserved and consumed as a meat substitute.

Cowpea is also grown as a dual-purpose crop — the green pods are used as a vegetable and the remaining parts as livestock fodder. In some parts of Africa, it is used to fortify cassava, plantain, cereal-based meals and yoghurt. In many localities in Limpopo and Mpumalanga provinces, cowpea leaves are harvested fresh as a vegetable for soup preparation or cured for future use during winter when there is no rain to sustain crop production. The trading of seeds and processed foods provide both urban and rural opportunities for earning regular income. The leaves and stalks can be utilised as animal fodder.

NUTRITION

Cowpea is rich in fibre, protein, iron, potassium, and low in fat and calories. A cup of cowpea possesses 11.1 g fibre, 13.22 g protein, 4.29 mg iron, 475 mg potassium, 0.91 g fat and 198 calories. Along with that, various amino acids such as 0.61 g of tryptophan, 0.41 g of histidine, 0.188 g of methionine and 0.894 g of lysine are contained in cowpea seed.

PRIMARY SOURCES

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Lablab (*Lablab purpureus*)

TAXONOMY AND NOMENCLATURE
Family: Fabaceae (alt. Leguminosae) Subfamily: Faboideae Tribe: Phaseoleae Subtribe: Phaseolinae.
CROP MORPHOLOGY
Growth habit It is a perennial herb, frequently grown as an annual. Usually twining to reach 1.5 to 15 m, but bushy, semi-erect, and prostrate forms exists. Probably no other legume shows such variation in form and habit. The tap-root is well developed with many laterals and well developed adventitious root. **Stem** Cylindrical, twining up to 6 meters in length, hairy or glabrous, usually 2-3 meters, but often to 10 meters long. Other forms, dwarf and bushy. **Leaves** Leaves alternate, trifoliate, leaflets ovate, 5-15 cm x 4-15 cm, often hairy. Leaflets very broad, ovate, the lateral ones lopsided, 7.5 - 15 cm long and nearly as broad, rather abruptly acuminate. **Inflorescence** Inflorescence is a stiff axillary raceme with many flowers with peduncles that are somewhat compressed. **Flowers** Flowers are formed in clusters of 4 - 5 and are white, pink, red or purple in colour. Each flower has two large basal bracts with uniform anthers and upper 2 sepals that are purple to pink or white. **Pods** Pods flat or inflated, pubescent or smooth, papery, straight or somewhat curved, white, green or purplish in colour. They vary in length from approximately 5 - 20 cm in length and 1- 5 cm in width. They may be crescent-shaped to more or less straight and ventrally deeply curving. Cultivars grown for vegetables have pods with thick, fleshy skins with practically no fibre. Pods

may be septate or non-septate; in the former each seed occupies a separate compartment in the pod, while in the latter the pods have bloated appearance. Each pod normally contains three to six seeds. They are generally less than 1.25 cm in length and may be rounded or oval or rather flattened, white, cream, red, brown or black. The hilum is white, prominen and oblong, usually covering one third of the seed

Seeds

Seeds vary in size and colour, normally up to 12.5 cm in length, colour ranging from white, red, brown, black or speckled, rounded or oval, hilum white, prominent, approximately 10 mm in length, average weight of 100 seeds is 25 - 40 g. Germination is epigeal.

DISTRIBUTION

L. purpureus is an old world food crop that is thought to have originated in Africa or India. It is now widely cultivated pan-tropically.

BOTANY AND ECOLOGY

Soil requirements

Grows in a wide range of soils from deep sands to heavy clays, provided drainage is good, and from pH 4.5-7.5. Low salinity tolerance with symptoms being chlorotic leaves, reduced growth and plant death.

Water

Adapted to annual rainfall regimes of 650-3 000 mm. Drought tolerant when established, and will grow where rainfall is < 500 mm, but loses leaves during prolonged dry periods. It is capable of extracting soil water from at least 2 m depth even in heavy textured soils. Will tolerate short periods of flooding but intolerant of poor drainage and prolonged inundation.

Temperature

Grows best at average daily temperatures of 18-30°C and is tolerant of high temperatures. Able to grow at low temperatures (down to 3°C) for short periods. Frost susceptible, but tolerates very light frosts. Will grow at altitudes from sea level to elevations of up to 2 000 m a.s.l in tropical environments.

Light

Intolerant of moderate to heavy shading.

Reproductive development

Short-day flowering response, with early flowering types available. Other varieties are much earlier flowering than others with some landraces flowering as early as 55 days after sowing.

Known to have some outcrossing but observations suggest that this is usually minimal. Being an annual or weak perennial, lablab flowers and sets seed in the first season of growth.

Defoliation

Three harvests possible from annual types, but will not stand heavy grazing of stems. For green manure, the crop should be cut before flower initiation. More tolerant of grazing than cowpea, and more harvests possible. As a forage, the crop should be utilised before flowering.

DROUGHT TOLERANCE

Lablab is especially adapted to drought due to its ability to extract soil water from at least 2 m depth even in heavy textured soils

CLIMATE CHANGE ADAPTATION

Due to its drought tolerance, lablab might offer comparable opportunities for African agriculture in the view of global change.

GENETIC RESOURCES AND BREEDING

Although most domesticated material is either *ssp. purpureus* or *ssp. bengalensis*, *ssp. uncinatus* has been domesticated in Ethiopia. Studies in lablab have shown that the perennial types have considerable genetic and morphological diversity.

CROP PROTECTION

The pod -boring insect *Adisura atkinsoni* can reduce seed yields but has been controlled experimentally by strain HB-III of *Bacterium cereus* var. *thuringensis*. Other insect pests include Heliothis armigera, Exelastis atomosa and Maruca testulalis. Bruchid beetles (*Callosobruchus spp.*) damage seed during growth and storage. Lablab roots are attacked by several nematodes: *Helicotylenchus dihystera*, *Meloidogyne hapla* and *M. incognita*. Anthracnose (caused by *Colletotrichum lindemuthianum*), leaf-spot (caused by *Cercospora dolichi*) and powdery mildew (caused by *Leveillula taurica* var. *macrospora*) have been reported. A stem rot caused by *Sclerotinia sclerotiorum* may attack the plant under wet conditions. In Australia, cultivar Rongai is fairly disease-free and generally lablab is more tolerant to root diseases than cowpeas.

Weed potential

None due to its short-lived nature and poor longevity of seed. Reported as a weed in cropped areas in some humid-tropical locations where individual plants may live up to 3 years, but no report as an environmental weed.

PRODUCTION AND TRADE

There is limited information on production and trade of lablab.

IMPORTANCE AND UTILISATION

Lablab purpureus is grown as a pulse crop (crop harvested for dry seed) in Africa, Asia, and the Caribbean. It is also consumed as a green vegetable (green bean, pod, leaf). Protein isolate from the bean can be used as a food additive for improving cake quality. *L. purpureus* is also used as forage,

hay, and silage. As forage, it is often sown with sorghum or millet. The leaf is very palatable but the stem is not. The seeds are moderately palatable. Overall, it is one of the most palatable legumes for animals
NUTRITION
Dry seed has 33% starch as the major component, protein 25% of dry weight, a very low fat content of only 0.8% and high dietary fibre constituting 7.2%. With 7.2% fibre lablab would be very ideal for diabetic, obese and hyper-cholestreamia patients. Oligosaccharides are a group of carbohydrates which have been reported to cause flatulence and include raffinose and stachyose found at 3.5%. Other components include phytic acid of 82.0 mg/g, phosphorus 430mg/g and phytates phosphorus 243 mg/g. The leaves also are rich in protein (up to 28 percent) and, at least among legumes, they are one of the best sources of iron (155 mg per 100 g of leaves, dry weight).
PRIMARY SOURCES
http://www.tropicalforages.info/key/Forages/Media/Html/Lablab_purpureus.htm http://www.lablablab.org/html/botany-Taxonomy.html

Marama Bean (*Tylosema esculentum*)

TAXONOMY AND NOMENCLATURE
Tylosema comprises 5 species and occurs in southern and eastern Africa. Some taxonomists do not consider Tylosema a separate genus, but include it in Bauhinia.
CROP MORPHOLOGY
Perennial herb or shrub, with tuberous root; stems prostrate and trailing, up to 6 m long, herbaceous or lower parts woody, rusty-hairy, with axillary forked tendrils 1–4 cm long. Leaves are alternate, with a leaf petiole 1.5 – 3 cm long. Leaf blade is 2-lobed for more than half its length, glabrous or pubescent beneath Inflorescence a lateral raceme up to 16 cm long and a peduncle 2–4 cm long. Flowers are bisexual, zygomorphic, 5-merous and heterostylous. Fruits are ovoid to oblong pods that are 3.5–6 cm long and 3–4 cm wide. Seeds ovoid to globose, 1.3–2.5 cm long and 1.2–1.5 cm wide. Seeds are reddish to brownish black in colour. 1000 seeds weight about 2 – 3 kg.
DISTRIBUTION
Marama bean (*Tylosema esculentum*) occurs naturally in the drier areas of Southern Africa, where it is harvested as a wild plant for human consumption. It is widespread in these areas, with large populations in Kgalagdi (Botswana), Eastern parts of Namibia, while smaller populations are found in the South Africa provinces of Limpopo, North West and Gauteng.
BOTANY AND ECOLOGY
Marama bean occurs naturally in an extreme environment with high temperatures (typical daily maximum of 37°C in the growing season), low rainfall (100–900 mm) and long periods of drought. It is found on sandy and limestone (including dolomite) soils, but not on soils developed over granite or basalt. Marama bean is found in grassland and wooded grassland vegetation. It occurs in localized patches. Propagation of marama bean is by seed. Scarification improves seed germination. Seeds are sensitive to water logging hence seed bed should not be waterlogged. Marama bean takes about 9–10 days to emerge after planting. Once germinated the seedlings develop rapidly. Marama bean flowers from October to March. It is predominantly outcrossing and may be self-incompatible; it is pollinated by insects. In cultivation fruit and seed set tend to be low. In southern Africa the stems die back during the dry and cool period (May–August), but the tuber

remains viable and produces new stems when the temperature rises. Marama bean does not form root nodules and relies on soil nitrogen. Young tubers of marama bean of 1-year-old and about 1 kg in weight are preferred. Tubers may reach 10 kg after a few years and tuber weights of up to 300 kg have been reported.
DROUGHT TOLERANCE
Its drought-adaptive mechanisms include closure of leaves, the maintenance of green-leaf area under drought by early stomatal closure, and the use of moisture reserves in the tuber (which shrinks greatly in dry years). Marama bean plants have long trailing stems that creep along the ground and avoid the effects of the strong destructive windstorms of the Kalahari. In addition, marama bean uses its tubers as water reservoirs.
CLIMATE CHANGE ADAPTATION
Marama bean could be a potential crop of the future well adapted to various agro-ecological conditions and climate change in particular.
GENETIC RESOURCES AND BREEDING
No substantial germplasm collections are known to exist. The International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia, the National Genebank, Muguga, Kenya, and the Plant Genetic Resources Unit of the Agricultural Research Council, Pretoria, South Africa, have 1 accession each.
PESTS
There is limited information on crop protection of Marama Bean
PRODUCTION AND TRADE
There is no information on production and trade of Marama Bean
IMPORTANCE AND UTILISATION
The seeds are eaten boiled or roasted. They may be boiled with maize meal or ground into flour to prepare a porridge or a coffee- or cocoa-like drink. Roasted seeds are sometimes sold locally but only on a small scale. Marama beans have a pleasant sweet flavour when boiled or roasted, comparable to roasted cashew nuts or almonds, although bitter types are known. The roasted seeds have sometimes been used by Europeans in southern Africa as a culinary substitute for almonds. Immature seeds and stems may be eaten cooked as a vegetable or in soups. The seed oil is used in Botswana for cooking and for making butter. Young tubers are eaten baked, boiled or roasted, as a vegetable dish. Tubers older than 2 years become fibrous and bitter and are usually not eaten, but they are an important emergency source of water for humans and animals. The pods and tubers are recorded to be eaten by animals, but it is not clear whether the foliage is browsed, as contradictory reports exist. Marama bean may have potential as a ground cover or ornamental.
NUTRITION
The marama bean contains 34.71% protein and is a good source of this nutrient. The fat content is 39.93%. The amount of energy contained in the marama bean is 2.28 MJ/100 g. Marama bean is high in calcium (241 mg/100 g), a mineral essential for maintaining the health of bones and teeth. It contains iodine (0.06 mg/ 100 g), needed for cognitive development. It is adequate in magnesium

(274.5 mg/100 g). Analyses of trace minerals in the marama bean show that it contains iron (3.95 mg/100 g). The marama bean contains zinc (6.2 mg/100 g).
OPPORTUNITIES
Marama bean is regarded as having considerable potential as a crop for arid and semi-arid regions. It has potential for its roasted seeds and as a source of oil. However, before large-scale cultivation can be promoted, more information is needed on its ecological requirements, adaptability to cultivation and agronomy.
PRIMARY SOURCES
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ROOT AND TUBER CROPS

Sweet potato (*Ipomoea batatas*)

TAXONOMY AND NOMENCLATURE
Ipomoea batatas is a tuber-producing herbaceous dicotyledonous perennial vining plant in the Convolvulaceae (morning glory family) that originated in Central America and is now widely grown as a food crop in tropical and subtropical regions worldwide. Although some varieties are referred to as yams, they are not true yams, which are a distinct set of species of the genus Dioscorea, in the monocot family Dioscoreaceae, native to Asia and Africa.
CROP MORPHOLOGY
Growth habit Sweet potato is an herbaceous and perennial plant. However, it is grown as an annual plant by vegetative propagation using either storage roots or stem cuttings. Its growth habit is predominantly prostrate with a vine system that expands rapidly horizontally on the ground. The types of growth habit of sweet potatoes are erect, semi-erect, spreading, and very spreading. **Root system** The sweet potato root system consists of fibrous, lateral roots that absorb nutrients and water, and anchor the plant. Storage roots store photosynthetic products. The root system in plants obtained by vegetative propagation starts with adventitious roots that develop into primary fibrous roots, which are branched into lateral roots. As the plant matures, thick pencil roots that have some lignification are produced. Other roots that have no lignification, are fleshy and thicken a lot, are called storage roots. **Stem** A sweet potato stem is cylindrical and its length, like that of the internodes, depends on the growth habit of the cultivar and of the availability of water in the soil. The erect cultivars are approximately 1 m long, while the very spreading ones can reach more than 5 m long. Some cultivars have stems with twining characteristics. The internode length can vary from short to very long, and, according to stem diameter, can be thin or very thick. Depending on the sweet potato cultivar, the stem colour varies from green to totally pigmented with anthocyanins (red-purple colour). The hairiness in the apical shoots, and in some cultivars also in the stems, varies from glabrous (without hairs) to very pubescent. **Leaves** The leaves are simple and spirally arranged alternately on the stem in a pattern known as 2/5 phyllotaxis (there are 5 leaves spirally arranged in 2 circles around the stem for any two leaves be

located in the same vertical plane on the stem). Depending on the cultivar, the edge of the leave lamina can be entire, toothed or lobed. The base of the leaf lamina generally has two lobes that can be almost straight or rounded. The shape of the general outline of sweet potato leaves can be rounded, reniform (kidney shaped), cordate (heart-shaped), triangular, hastate (trilobular and spear-shaped with the two basal loves divergent), lobed and almost divided. Lobed leaves differ in the degree of the cut, ranging from superficial to deeply lobed.

Leaves can be green-yellowish, green or can have purple pigmentation in part or all the leaf blade. Some cultivars show purple young leaves and green mature leaves. The leaf size and the degree of hairiness vary according to the cultivar and environmental conditions. The hairs are glandular and generally are more numerous in the lower surface of the leaf. The leaf veins are palmated and their colour, which is very useful to differentiate cultivars, can be green to particularly or totally pigmented with anthocyanins.

Flowers

Sweet potato cultivars differ in their ability of flower. Under normal conditions in the field, some cultivars do not flower, others produce very few flowers, and others flower profusely. The inflorescence is generally a cyme in which the peduncle is divided in two axillary peduncles; each one is further divided in two after the flower is produced (biparous cyme). In general, buds of first, second, and third order are developed. However, single flowers are also formed. The flower buds are joined to the pedundle through a very short stalk called pedicel. The colour of the flower bud pedicel, and peduncle varies from green to completely purple pigmented. The flower is bisexual. Besides the calyx and corolla, they contain the stamens that are the male organs or androecium and the pistil that is the female organ or gynoecium.

The length of the filaments is variable in relation to the position of the stigma. The anthers are whitish, yellow or pink, with a longitudinal dehiscence. The pollen grains are spherical with the surface covered with very small glandular hairs. The gynoecium consists of a pistil with a superior ovary, two carpels, and two locules that contain one or two ovules. The style is relatively short and ends in a broad stigma that is divided into two lobes that are covered with glandular hairs. At the base of the ovary there are basal yellow glands that contain insect-attracting nectar. The stigma is receptive early in the morning and the pollination is mainly by bees.

Storage-root

The storage roots are the commercial part of the sweet potato plant. Most cultivars develop storage roots at the nodes of the mother stem cuttings that are underground. However, the very spreading cultivars produce storage roots at some of the nodes that come into contact with the soil. The parts of the storage roots are the proximal end that joins to the stem, through a root stalk, and where many adventitious buds are found from which the sprouts are originated; a central part which is more expanded; and the distal end that is opposite to the root stalk. The adventitious buds that are located in the central and distal part usually sprout later than those located in the proximal end.

DISTRIBUTION

Its large, starchy, sweet-tasting, tuberous roots are particularly important as a food crop in Southeast Asia, Oceania, and Latin America.

BOTANY AND ECOLOGY
Altitude The crop prefers lower and mild elevation zones. **Soils** Sweet potatoes do best on soils of friable/loose nature (fertile sandy soils), which permit expansion of tubers. Grows poorly in clay soils. They do not grow well in water logged, too shallow and stony soils as they inhibit growth and retard tuber formation. The crop is sensitive to saline and alkaline soils. Too high fertility may result in excessive vegetative growth at the expense of tuber and starch formation. **Temperatures** It grows best at average temperatures of 24 to 28°C and when temperatures fall below 12°C or exceeds 35°C growth is retarded. **Water** 750 – 1000 mm of rainfall is ideal but crop can withstand drought. During the first six weeks of establishment, yields are drastically reduced if drought occurs.
DROUGHT TOLERANCE
The root system of sweet potato has a big surface that allows easy access to available soil water. It is very rich in antioxidants such as vitamin C, carotenoids and polyphenolic substances, which are powerful to scavenge hydroxyl and peroxyl radicals and to control oxidation of lipid and protein of cell membrane.
CLIMATE CHANGE ADAPTATION
Sweet potato may be a potential climate planning change adaptation crop particularly with respect to its moderate drought tolerance, adaptability to multiple agro-ecological conditions and tolerance to destructive winds of tropical cyclones. Sweet potato may be thus viewed as a climate change resilient crop.
GENETIC RESOURCES AND BREEDING
There are two broad categories of sweet potato: The staple type with white flesh and white or purple skin has a high starch and dry- matter content. The dessert type with orange flesh and orange skin with a high sugar and beta-carotene content. Commonly three distinct types of sweet potato available for commercial production include: (i) Orange/copper skin with orange flesh, e.g.: Beauregard, Hernandez, Beerwah Gold, NC-3, LO-323, Centennial, Darby and Jewel (ii) White/cream skin with white/cream flesh e.g.: Hawaii, Kestel. Blesbok, which has cream flesh colour, has a high yield and a good storage life (iii) Red/purple skin with cream/white flesh, e.g. Northern Star, Red Abundance, Rojo Blanco.
CROP PROTECTION
Weed Control

Weeds may be a problem early in crop growth before vigorous vine growth covers the beds as plants become established. A number of control strategies may be used: After bed formation, irrigating should be applied to germinate any weed seed. Herbicide before planting is effective. Vigorous early vine growth is recommended to outgrow weeds.

Sweet potato weevil

This is the most serious pest of sweet potato. Adults are ant-like and lay eggs on stems and roots. The larvae burrow into the roots, making them unmarketable. They can pupate in the stems and be transferred in planting material. Once established in a crop, this pest is difficult to control. Pre-plant treatment of cut-tings with chlorpyrifos combined with foliar applications of chlorpyrifos at 5 and 10 weeks from planting provides significant control. Planting material collected from an infected crop would require insecticide dipping before planting.

Other pests

Leaf-feeding caterpillars may cause problems if infestation is severe enough to cause significant leaf reduction. At the start of the wet season, hungry magpie geese can cause serious damage by trampling crops and eating the roots. Black-footed tree rats are also a problem.

DISEASE CONTROL

Mycoplasma (little leaf disease)

Infected plants have small, pale-yellow, stunted leaves and stems. The infection is spread by leafhoppers and if plants are infected while young, yields are greatly reduced. Control is by regular monitoring for symptoms and the removal and destruction of infected plants.

Fungal disease

Soil-borne fungal diseases can infect the roots but are not a large problem on well-drained, sandy soils. Any organic matter added to the soil should be well decomposed before planting. Feathery mottle virus has been detected in various sweet potato growing areas but research has shown that the infection had no significant effect on yield.

PRODUCTION AND TRADE

Total global commercial production of sweet potatoes in 2010 was 106.6 million metric tons, harvested from 8.1 million hectares. China is the leading producer of sweet potatoes accounting for around 72% of the global total, due in part to the use of sweet potatoes to make ethanol. African nations including Uganda, Nigeria, and Tanzania, as well as Indonesia, Vietnam, India, and Japan also rank among the top ten producers.

IMPORTANCE AND UTILISATION

Important starchy crop that is boiled or roasted, served with tasty sauces, or worked to make a kind of bread. The leaves and young shoots that grow from tubers, are usually used as ordinary vegetables, but in some areas they serve only as animal fodder. Industrially, sweet potato can be

exploited for the production of flour and starch (sweet potato starch, which contains approximately 24-26% starch), but they also derive glucose syrup, alcohol, spirits and other alcoholic beverages. Other uses include production of dyes and for food production.
NUTRITIONAL VALUE
80% - 90% of sweet potato dry matter is made up of carbohydrates, consisting mainly of starch and sugars with lesser amounts of pectins, hemicelluloses and cellulose. On average, starch constitutes 60 - 70% of the dry matter, but the proportion of starch to other carbohydrates varies greatly. Sweet potato also contains protein (0.46% - 2.93%), dietary fibre (0.49% - 4.71%), lipid (0.06% - 0.48%) and ash (0.31 - 1.06%). It contains essential mineral nutrients such as Ca, P, Mg, Na, K, S, Fe, Cu, Zn, Mn, Al and Vitamin B. The average mineral and vitamin content 117 mg calcium, 1.8 mg iron 3.5 mg carotene, 7.2 mg vitamin C, 1.6 mg vitamin E and 0.56 mg vitamin K 100 g^{-1} fresh weight of tubers.
PRIMARY SOURCES
• http://www.fao.org/livestock/agap/frg/AHPP95/95-203.pdf • http://eol.org/pages/580962/hierarchy_entries/57255610/overview • www.nda.agric.za

Taro (*Colocasia esculenta*)

TAXONOMY AND NOMENCLATURE

Taro (*Colocasia esculenta*) belongs to the Araceae family, being part of the Aroideae sub-family, whose members are more commonly referred to as aroids. The family comprises about 110 genera with over 2 500 species divided amongst seven sub-families. Members of the aroid sub-family are found in almost every climatic region. In the South African context, two varieties are of interest. The main distinguishing factor between the two varieties lies in the shape and size of their main corms and cormels. The esculenta (dasheen) variety produces a large main corm and few, small side cormels, the edible part of which is the large central corm. The antiquorum (eddoe) varieties are characterised by a relatively smaller central corm and numerous well-developed side cormels which, in South Africa, are mostly consumed while the central corm is usually kept for seed.

CROP MORPHOLOGY

Perennial, glabrous, herb growing to a height of 1 m or more, with a massive, fleshy corm at the base, and lateral, thick, edible runners. Root system adventitious, fibrous, and shallow. Storage stem (corm) massive (up to 4 kg), cylindrical or spherical, up to 30 x 15 cm, usually brown, with lateral buds located above leaf scars giving rise to new cormels, suckers or stolons. Leaves are arranged in a loose rosette; blades pointing downward, 23-55 × 12-38 cm, cordate or lanceolate, sub-coriaceous, green above, glaucous below, the apex obtuse, acute or shortly acuminate, the base peltate-cordate, the margins more or less wavy, with a sub-marginal collecting vein; petioles erect, to 85 cm long, inserted 3-7 cm from base of blade. Inflorescences axillary, ascending, solitary; peduncles nearly as long as the petiole, cylindrical; spathe fleshy, to 35 cm long, the tube green, the blade lanceolate, not much wider than the tube, yellow to orange, flexing open near the base, then deflexing and dropped; spadix yellow, much shorter than the spathe, the sterile flower zone and the distal appendage shorter than the fertile zones. Fruit is a many-seeded berry, densely packed and forming a fruiting head. Seeds are ovoid to ellipsoid, less than 2 mm long, with copious endosperm (Acevedo-Rodríguez and Strong, 2005; Langeland et al., 2008).

DISTRIBUTION

Taro is a crop that falls within the category of underutilised crops. The origins of taro are still a point of debate, although its history in several centres of origin is well documented, with the main centre of origin thought to be tropical Asia. What is certain is that taro is perhaps one of the oldest (if not the oldest) crops known to mankind. Suggestions of how long taro has been in existence range between 9 000 - 10 000 BC. The domestication of taro may have occurred several times in different locations ranging from India to South China and northern Australia, with the spread of taro from these centres into Africa through the Mediterranean and from there to the rest of Africa through trade and migration.

In South Africa, taro is a traditional "indigenised" crop. Its Zulu name amadumbe derives from the fact that it is most common in coastal areas and the hinterland of KwaZulu-Natal province. In addition, amadumbe is an important staple crop in the sub-tropical coastal areas starting at Bizana district in the Eastern Cape and the rest of coastal KwaZulu-Natal. The crop is also cultivated, to a lesser extent, in the sub-tropical and tropical regions of Mpumalanga and Limpopo provinces.

BOTANY AND ECOLOGY

Taro can grow in a wide range of soils from upland or dryland soils that are well drained, non-flooded soils to soils that are in high rainfall areas or saturated for prolonged periods of time. Taro can grow in areas that only it and rice can grow because of standing water during the growing season. The upland taro is usually grown on hillsides in soil that is marginal in fertility and productivity. Soils in these areas are usually well drained and friable. While lowland or wetland taro is usually planted in low-lying areas where there is an abundant supply of water. The soils in these areas are normally alluvial and of high native fertility and production. Taro can grow in areas ranging from sea level to 1 800 m in elevation under daily average temperature of 21-27°C and rainfall of > 800 mm annually. Taro is usually planted at wide spacing of 1 x 1 m at a density of 10 000 plants/ha in dry areas and at spacing as close as 0.45 x 0.45 m or approximately 49 000 plants/ha in wetland areas.

DROUGHT TOLERANCE

Local eddoe landraces have been observed to be drought tolerant through a combination of drought avoidance and escape mechanisms. The observations also showed that the eddoe type landraces could be promoted further inland due to their adaptation to low levels of water use. Observed drought avoidance was achieved through stomatal regulation, energy dissipation and canopy size adjustment. Drought escape was demonstrated through phenological plasticity.

CLIMATE CHANGE ADAPTATION

Climate change projections for taro production for South Africa have projected relatively higher yields and taro expansion further inland in Mpumalanga. Therefore, farmers could adapt by planting taro somewhat further inland than many do at the present time, especially in slightly higher altitude areas which nowadays may not be warm enough for successful taro cultivation. In some places production could more than double from present day yields. Intercropping taro with other drought tolerant crops such as Bambara groundnut has also been shown to lead to improved resource utilisation and could be an important adaptation strategy to bolster the expansion of taro production areas.

GENETIC RESOURCES AND BREEDING

Currently, taro is mostly cultivated from local landraces using corms and huli. There are no commercially available improved varieties although work is ongoing at the Agricultural Research Council to develop new taro varieties.

CROP PROTECTION

Pests and diseases of taro for local South African landraces have not been the focus of any studies. Studies to date have focussed on the agronomy, drought tolerance and water use as well as nutritional value of taro landraces. Although it is not well documented, *Phytophthora* leaf blight and corm rot have been observed. Aphids have been observed to be a major pest of taro with plant hoppers also observed, although the latter could be regarded a minor pest in South Africa.

PRODUCTION AND TRADE

Globally, taro is ranked 14th among staple vegetable crops, with about 12 million tons being produced from about 2 million hectares of land and with an average yield ~ 6.5 t ha^{-1} (FAOSTAT, 2012). The bulk of taro production is in Africa.

In South Africa, taro is generally consumed as a subsistence crop, although some commercialisation has recently occurred. South African yields are, however, relatively low when compared with those of central African countries, primarily in response to limited water availability.

IMPORTANCE AND UTILISATION
Ethnobotanical: Taro was the most important food throughout the Hawaiian Islands. The mature root is boiled as a starchy vegetable. It was the staple of the Hawaiian diet and the plant used to make poi. The leaves are high in minerals and vitamins A, B, and C. These large leaves are cooked like mustard or turnip greens and the resulting product is called callaloo in the Caribbean. The young leaves are cooked and used for human consumption as a very nutritious vegetable and the corms are used as staple in place of rice or potato. These young leaves are boiled or covered with coconut cream, wrapped in banana or breadfruit leaves and cooked on hot stones. The corms are generally cooked by baking, boiling or baking in the traditional ovens. The starch contained in the large corms of taro is highly digestible, therefore making it a good source for carbohydrate and to a lesser degree a source of potassium and protein. Taro corms have been used in the production of taro chips, dehydrated stable commodities, starch, flour, and in non-food application of taro starch in the manufacture of biodegradable plastics.
NUTRITIONAL VALUE
Taro corm has been reported to have 70–80% (dry weight basis) starch with small granules. Taro contains about 11% protein on a dry weight basis. In general, the fat contents of taro root range from 0.3-0.6%. Taro is a good source of minerals including iron (8.66-10.8 mg/100 g), calcium (31-132 mg/100 g), sodium (82-1521.34 mg/100 g), magnesium (118-415.07 mg/100 g), phosphorus (72.21-340 mg/100 g), zinc (2.63 mg/100 g), copper (1.04 mg/100 g) and an excellent source of potassium (2271-4276.06 mg/100 g). High potassium to sodium ratio food recommended for patient with high blood pressure. Vitamin C and vitamin B complex (niacin, riboflavin and thiamine) which are important constituents of human diet, are present in appreciable quantity in corms and leafs of taro.
OPPORTUNITIES
Farmers in the Umbumbulu rural district of KwaZulu-Natal are managing to market the crop to national retail outlets (e.g. Woolworths and Pick ‘n Pay). This has elevated the production of taro and possibly resulted in more land being allocated to taro production in KwaZulu-Natal. There are opportunities for product development e.g. chips, flour and other condiments, that still need to be explored. These could create further income generating opportunities for taro.
PRIMARY SOURCES
• Mabhaudhi (2012) • Lebot (2009) • Mare and Modi (2014)

TRADITIONAL/LEAFY VEGETABLES

Amaranth (*Amaranthus spp*.)

TAXONOMY AND NOMENCLATURE

The genus *Amaranthus* has not been clearly defined. It has been classified into two sub-genera, *Acnida* and *Amaranthus* which are monoecious and dioecious species, respectively. Due to the diversity of this genera, further infrageneric classification. Currently, *Amaranthus* includes 3 recognized sub-genera (*Acnida*, *Amaranthus*, and *Albersia*) and approximately 70 species classified based on inflorescence, and flower characters.

CROP MORPHOLOGY

Mature plant

Amaranth species are erect or spreading annuals with a rough appearance. The species differ in flower, leaf and stem colour, with marron and crimson being the most common plant colours. Flowers range from green to golden in colour. Deep crimson varieties have a tendency to be very outstanding when in full bloom. Depending on the species, growth habitat and environment, height of the plant varies between 30 cm and 2 m.

Stems

Stems are usually longitudinally grooved. Grain amaranth plants are dicots plants with thick, tough stems similar to those of sunflowers.

Leaves

The leaves thin stalks and differ in size and colour. These are alternate, usually simple, with entire margins and diverse markings.

Flowers

Small green flowers are borne in dense, elongated clusters, usually on the branch tips. They are borne in spikes or plumes and are white, green, pink or purplish in colour.

Seed

Seeds are very small and up to 3000 seeds weigh one gram. They are shiny black, dark red or cream in colour.

DISTRIBUTION

Amaranth is extensively grown as a green, leafy vegetable in many temperate and tropical regions. Amaranth has spread around the world and has become established for food use (the grain or leaves) in places such as Africa, India and Nepal.

BOTANY AND ECOLOGY

Temperature

Amaranth is drought tolerant and requires warm temperatures. Temperatures below 18°C cease growth and temperatures between 25 and 30°C are optimum for growth. Lower temperatures and shorter days will induce flowering with a subsequent reduction in leaf yield. Frost damage should not be a problem because the crop grows during summer with the start of the rains. Amaranth is an annual crop and not mature completely in areas with short growing seasons.

Water

Amaranth is reported to be one of the most drought-tolerant vegetable crops. One trait that helps it in extremely dry conditions is an ability to wilt temporarily and then revive after rainfall occurs. The exposure of the plant to severe drought induces early flowering and stops the production of leaves. The crop cannot withstand waterlogging.

Soil

Amaranth is adapted to a variety of soil types, including marginal soils, but will do best on fertile, well-drained soils and deeper soils. Loose and friable soils with high organic matter content are ideal for an early and heavy yield. Amaranth requires good seed-soil contact without crusting for rapid germination and emergence. Amaranth requires pH of 6.4 and pH values below 5.3 can adversely affect growth.

DROUGHT TOLERANCE

The physiological basis of drought-tolerance in amaranth reveals a high capacity of osmotic adjustment which guarantees that the plant can continue to function under severe drought stress conditions. Amaranthus is a C4 plant and it is capable of using solar radiation and nutrients at high temperatures similar to sorghum and millets.

CLIMATE CHANGE ADAPTATION

Amaranth uses the C4 photosynthetic pathway that assures high photosynthetic activity and water use efficiency under high temperatures and high radiation intensity and is, therefore, an ideal crop for abiotic stress conditions under changing climates.

GENETIC RESOURCES AND BREEDING

Most of the species in Amaranthus are wild. Many of the species are found in wetlands or semi-desert life zones.

CROP PROTECTION

Weed control

Despite amaranth being often categorised as a weed, it is affected by other weeds such as lambsquarter, redroot pigweed, kochia, cheatgrass during growth. Early weeds are controlled by tillage or a contact herbicide prior to planting the amaranth. Amaranth grows slowly during the first several weeks, so three or four cultivations may be needed during this period to control weeds (no selective herbicides are labelled for use with amaranth). Once amaranth gets to be 15 cm tall, it will begin growing rapidly, and its shade can outperform late emerging weeds.

Pest control

There is a wide range of insects that attack amaranth in South Africa; various snout beetles, moth larvae, fleas, stinkbugs and blowflies. Tarnished plant bug and amaranth weevil are regarded as potentially significant insect pests of amaranth. The insect most likely to affect yields is the tarnished plant bug, a sucking insect which often reaches high populations in the seed head during the critical seed-fill stage. Flea beetles damage the young leaf tissue. The adult amaranth weevil feeds on leaves, but the larval stage is more damaging because they bore into the central tissue of roots and occasionally stems, causing rotting and potential lodging. There are no synthetic insecticides labelled for amaranth, but various organic insecticides can be used, including certain pyrethrum and BT products. There are no fungicides labelled for amaranth.

Disease control

No significant disease problems have been conclusively identified for grain amaranth. One possible problem is a damping-off fungus, which can kill seedlings. Therefore, use disease-free seeds and avoid both overwatering and dense planting. Leaf amaranth suffers damage from the armyworm and the curly top virus disease, which is transmitted by the beet leafhoppers (Circulifer femellus).

PRODUCTION AND TRADE

Amaranth is not usually planted in South Africa but occurs as a volunteer crop after the first rains; it is harvested from the wild. The production levels of amaranth are not known. Under cultivated conditions, amaranth produces fresh leaf yields of up to 40 t/ha.

IMPORTANCE AND UTILISATION

Leaves of amaranth are used as a steamed vegetable in soups and stews. They are also cooked to accompany starch foods.

Grain amaranth is ground and used in breads, noodles, pancakes, cereals, granola, cookies and other flour-based products. The grain can be popped like popcorn or flaked like oatmeal. Its use as a forage is not well documented though vegetable amaranths is believed to produce 30 to 60 t ha^{-1} of silage (80 % moisture). In areas where corn silage yields are low more research is needed to make grain amaranth a suitable silage alternative.

NUTRITIONAL VALUE

Both the seeds and leaves of *A. tricolor* are known to contain protein of unusual high quality and are richer in vitamins and minerals than cereals. Amaranth leaves have protein content of 17-19% and have the advantage of having a more balanced composition of essential amino acids. Approximately 100 g of amaranth vegetable leaves cooked in the absence of oil makes up 45% of

the daily vitamin A requirement. Amaranth has three times more vitamin C, niacin and calcium compared to other leafy vegetables like spinach.
PRIMARY SOURCES
• http://www.nda.agric.za/docs/Brochures/Amaranthus.pdf • http://www.newworldencyclopedia.org/entry/Amaranth • Kgang (2010) • Liu and Stutzel (2002)

Spider Plant (*Cleome gynandra*)

TAXONOMY AND NOMENCLATURE
Cleome gynandra (L.) belongs to the botanical family Capparaceae (formerly Capparidaceae), subfamily Cleomoideae. The family contains about 700 - 800 species, divided into 45 genera. The genus Cleome, with over 200 species, consists of highly polymorphic herbaceous plants.
CROP MORPHOLOGY
Morphology Annul herb that is erect, and 250 - 600 mm tall. The stem is sticky with glandular hairs and marked with longitudinal parallel lines. Leaves are compound, with 3 - 5 leaflets. The leaf stalk is 20 - 50 mm long with glandular hairs. The leaflets radiate from the tip of the leaf stalk and are smooth or with glands. They taper toward the base on the under surface and are smooth to finely glandular. Often they have multi cellular hairs scattered on the main nerves. The inflorescence is a terminal raceme, with many flowers. The flower stalk is 10 - 20 mm long with glandular hairs. Petals are white, sometimes fading to rose pink, rounded at the apex and abruptly narrowed to a basal claw. The fruits are in capsule form. The capsule is linear and sub-erect to spreading. The seeds are brown, circular in outline, 1.5 mm in diameter, with an obscurely netted surface.
DISTRIBUTION
The Cleome genus is widely distributed in the drier parts of the tropics and subtropics, but occurs mostly in Africa. It is also found in countries in Asia, Africa and the Americas, where it grows and is regarded as a weed.
BOTANY AND ECOLOGY
The species is adapted to a wide range of environmental conditions. It grows well from sea level up to 2400 m a.s.l, and tolerates high and low temperatures, but thrives from 18 - 25°C. Plants do not grow well under shade, as they require high light intensity. The species is a C4 plant, and hence combines efficient water utilization with high photosynthetic capacity at high temperatures. This allows it to grow in areas with short periods of useful rainfall. The species requires soils with high organic matter content, with adequate mineral reserves. Plants can grow on a wide range of soils, as long as they are deep and well drained, with a pH range of 5.5 - 7.0. The soil types range from sandy loam to clay loams.
DROUGHT TOLERANCE
Cleome gynandra is a C4 plant, making it better suited to drought and conditions with high levels of solar radiation and evaporation.
CLIMATE CHANGE ADAPTATION

Cleome uses the C4 photosynthetic pathway that assures high photosynthetic activity and water use efficiency under high temperatures and radiation intensity and is, therefore, an ideal crop for areas that are projected to experience declining rainfall and increasing temperatures, i.e. hot and dry
GENETIC RESOURCES AND BREEDING
There is little documentation on collections of *C. gynandra*. The species is still regarded as a wild, weedy or a volunteer crop, and is semi-cultivated. Farmers are using their own local selections/advances; there are few genetic studies and breeding work on *C. gynandra* reported in the literature.
CROP PROTECTION
Weed control Weeds can be hand-picked or shallow cultivation can be done. However, care should be taken to avoid root damage. **Pest and disease control** The most important pests are beetles and hurricane bugs (also known as Bagrada or painted bugs) (*Bagrada hilaris*). The hurricane bug can render establishment virtually impossible. Other pests are: pentatomids (*Acrosternum gramineum* and *Agonoselis nubilis*) and their parasitoids; locusts (*Schistocera gregaria*); nematodes (*Meloidogyne spp*.); flea beetles (*Phyllotreta mashonana* Jacq.); green vegetable bugs (*Nezara spp*.); cabbage sawfly (*Athalia spp*.); cotton jassids (*Empoasca spp*.) and aphids that cause leaf damage. Bagrada bugs damage plants by feeding on young leaves. Both adults and nymphs suck sap from leaves, which may wilt and later dry out. Considerable damage is caused to young plants, which may die off or have the growth points severely damaged. Significant damage may also be caused to older plants. The bugs, especially in the early stages of development, gather in masses and suck the sap from plants. Feeding by the bugs causes small puncture marks visible as white patches starting on the edges of leaves. Eventually the leaves wilt and become dry. Heavily attacked plants may have a scorched appearance. Cleome is host to the mildew fungus (powdery mildews *Sphaerotheca fuliginea*, *Oidiopsis taurica* and *Cercospora uramensis*). It is important to detect Bagrada bug before they cause damage to the crop. Weeding is vital, in particular removal of old crops and destruction of weeds. Handpicking and destruction of the bugs help to reduce damage. This is particularly important in the early stages of the crop. Growing strong smelling plants such as a garlic, onion or parsley near the crops is reported to reduce infestations. Encourage natural enemies: Eggs of Bagrada bugs are parasitised by tiny wasps.
PRODUCTION AND TRADE
Cleome gynandra is regarded as a wild, weedy and volunteer crop, and is semi-domesticated in home gardens or on fertile land near homesteads in most African countries (Kenya, Uganda, Botswana, Zambia, South Africa, Zimbabwe, Malawi, Nigeria, Cameroon, Namibia, Swaziland, Tanzania and Ghana). There is no information on production statistics.
IMPORTANCE AND UTILISATION
The vegetable is important as a leafy vegetable and is cooked in various ways. In India, it is consumed as a pot herb and flavouring in sauces. Leaves may be crushed to make a concoction that

is drunk to cure diseases such as scurvy. In other communities, leaves are boiled and marinated in sour milk for 2-3 days and eaten as a nutritious meal, which is believed to improve eyesight, provide energy and cure Marasmus. It is a highly recommended meal for pregnant and lactating women. Eating the vegetable is believed to reduce dizzy spells in pregnant women. Pregnant women are encouraged to eat the leaves in order to ease childbirth by reducing the length of their labour. The seeds are oleiferous, containing polyunsaturated oil, which is extracted by pressure and does not need refining. They are used as bird food. The seed cake has an excellent acid spectrum and can therefore be utilized in animal feeds.
NUTRITIONAL VALUE
Nutrient values per (% or mg/100 g edible parts) are as follows: Moisture content: 81.8 - 89.6; Crude protein: 3.1 - 7.7; Crude fibre: 1.3 - 1.4; Carbohydrates: 4.4-6.4; Ether extract:0.4-0.9; Total ash: 2.1-3.0; Potassium: 410; Calcium: 213-434; Magnesium: 86; Sodium: 33.6; Phosphorus: 12; Iron: 1-11 Zinc: 0.76; Copper: 0.46; B-carotene: 6.7-18.9; Ascorbic acid: 127-484; Oxalate: 8.8; Total phenolic: 520-9
PRIMARY SOURCES
• Chweya, James A. and Nameus A. Mnzava. 1997. Cat's whiskers. *Cleome gynandra* L. Promoting the conservation and use of underutilized and neglected crops. 11. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy • http://www.nda.agric.za • Mishra SS, Moharana SK and Dash MR. 2011. International Journal of Research in Pharmacy and Chemistry 1: 681 - 68

Jute Mallow (*Corchorus olitorius*)

TAXONOMY AND NOMENCLATURE
Jute (*Corchorus olitorius* L.; 2n ¼ 14) belongs to the Tiliaceae family. It is one of the cheapest and important commercial fibre crops in the world next to cotton. Corchorus olitorius is believed to have originated in Africa.
CROP MORPHOLOGY
It is an erect, annual herb that varies from 20 cm to approximately 1.5 m, depending on the cultivars. **Stems** The stems are angular with simple oblong to ceolate leaves, strongly branched and fibrous. **Leaves** Leaves are alternate, simple, lanceolate, 5 - 15 cm long, with an acuminate tip and a finely serrated or lobed margin. **Flowers** The flowers are small, 2 - 3 cm in diameter and yellow, with five petals. The flowers have both male and female organs and are pollinated by insects. The plant flowers from August to October and the seeds ripen in October. **Fruit** The fruit is a cylindrical capsule with many seeds.
DISTRIBUTION
It is native to tropical and subtropical regions throughout the world. It is produced as a very important vegetable in arid regions of the Middle East and Africa.
BOTANY AND ECOLOGY
Temperature It requires average temperatures ranging from 16 - 25°C. The optimum temperature is 25 - 32°C. Temperatures below 15°Care detrimental to the crop. **Rainfall**

Jew's mallow is sensitive to drought and it can perform well in areas with high rainfall (600 - 2 000 mm).

Soil requirements

Jew's mallow can grow in a wide range of soils, but prefers rich, well drained loam soil. It tolerates a pH ranging from 4.5 - 8.2. It requires moist soil, but sensitive to waterlogged conditions

DROUGHT TOLERANCE

Jews mallow is drought tolerant although the exact mechanisms for the drought tolerance are yet to be elucidated. However, the viscosity in C. olitorius seems to be related with soil moisture stress

CLIMATE CHANGE ADAPTATION

As a drought tolerant crop, it may be suited to areas that will experience declining rainfall amounts.

GENETIC RESOURCES & BREEDING

In South Africa, it is mostly grown using local landraces and there are no improved varieties.

CROP PROTECTION

Weed control

Plant establishment is slow and the plants become vulnerable to weed competition. Weeds must not be allowed to crowd or overgrow the young plants. When plants are 20 - 25 cm tall, hand hoeing is encouraged to suppress the growth of weeds.

Pest control

The most common pests attacking the plant are spider mites, grasshoppers, caterpillars, army-worms, flea beetles and red spider mites. Control by spraying with recommended pesticides. Root-knot nematodes (Meloidogyne spp.) cause stunting of plants. It can be controlled by crop rotation with other crops that are less susceptible to root-knot nematode.

Disease control

Only a few diseases affect Jews mallow. Damping-off caused by *Rhizoctonia*, *Pythium* or *Phytophthora spp*. occurs in seedbeds. These pathogens are managed through the use of raised beds, well-drained soils and not too much watering. Stem rot (*Sclerotium rolfsii*) is a common disease during the dry season, causing plants to wilt. Stem rot is managed by deep ploughing, using raised beds, crop rotation and allowing ample time for breakdown of green manure before planting.

PRODUCTION AND TRADE

There are no statistical data on production, yield and trade of jews mallow in South Africa.

IMPORTANCE AND UTILISATION

Jew's mallow is used as leafy vegetable. Immature fruit are dried and ground into powder to prepare a sauce. The dried leaves can be used as a thickener in soups. Tea can also be made from

the dried leaves. Jews mallow has medicinal value such scraping root decoction to treat toothache and as a tonic. Jews mallow can also be used as a source of fibre.
NUTRITIONAL VALUE
The leaves are very nutritious, rich in beta-carotene, iron, protein, calcium, thiamine, riboflavin, niacin, folate, vitamin C and E and dietary fibre. 100 g portion contains amount of 3 .79% protein, 6.73 g iron, 5.1 mg beta-carotene and 440 mg potassium.
PRIMARY SOURCES
• Roy et al. 2006 • www.nda.agric.za • Shiwachi et al. 2008 • tropical.theferns.info/viewtropical.php?id=Corchorus+olitorius

Nightshade (*Solanum Nigrum*)

TAXONOMY AND NOMENCLATURE
Kingdom: Plantae Division: Magnoliophyta Class: Magnoliopsida Order: Solanales Family: Solanaceae Genus: Solanum L. Species: Solanum nigrum L. Popular Name(s): Makoy, Deadly Nightshade, Garden Nightshade, Black Nightshade
CROP MORPHOLOGY
Description of the plant Matured plant Black nightshade is an annual herb that can grow up to 75 cm in height. Roots The plant has a slender tap root with a fibrous root system. **Stems** The stems are green, branching, round or angular, smooth or partially hairy and becoming woody with age. **Leaves** Leaves are simple, alternate, ovate or ovate-lanceolate. Leaf margins may be entire or with blunt teeth. Leaf hairiness is variable, however, the leaves are most often found to be slightly hairy. **Flower and fruit** The flowers are white with a yellow centre. The fruit is 5 to 12 mm in diameter, green when immature and turn purplish black at maturity.
DISTRIBUTION
It is widely distributed throughout the tropics and can be found in wild forms throughout East Africa.
BOTANY AND ECOLOGY
Temperature

Black nightshade requires optimum temperatures of 25 to 30 ºC. It prefers full sunlight and it is sensitive to frost.

Soil requirements

The plant prefers light, medium and heavy soils that are rich in organic matter. It can also do well in acid, neutral to basic soils.

DROUGHT TOLERANCE

Nightshade is drought tolerant but tolerance mechanisms in nightshade have not been studied.

CLIMATE ADAPTATION

Its drought and heat stress tolerance makes it an ideal crop for the changing climate.

GENETIC RESOURCES AND BREEDING

Grown using landraces and there are no improved varieties improved through conventional breeding techniques.

CROP PROTECTION

Weed control

An integrated control programme combining preventive, cultural, mechanical and chemical methods is most effective. Black nightshade can be a serious agricultural weed when it competes with crops.

Disease control

The most common diseases attacking black nightshade are among others, leaf blight, bacterial wilt, powdery mildew, etc. The use of disease-free seeds and hot water seed treatment is recommended to control early blight. Optimum growing conditions and good soil conditions can also help in limiting disease inducement.

Pest control

Major pests of black nightshade are, among others, black aphids, caterpillars and beetles. These pests can be controlled by crop rotation and wood ash dusted on the leaves. Onion and garlic are natural flea-beetle repellents.

PRODUCTION AND TRADE

There are no solid statistics on how much African nightshade is currently cultivated. But the crop is one of the most important indigenous leafy vegetables in West and Central Africa, and to a lesser extent East Africa.

IMPORTANCE AND UTILISATION

Medicinal: The juice of black nightshade is sometimes used to treat fever and alleviate pain. Its fruit is used as a cosmetic; as rubbing its seeds on the cheeks helps remove freckles. Children

extensively eat the mature fruit. It has been used for diabetes as well. In Northern India, the boiled extracts of its leaves and fruits are used to alleviate the discomfort caused by liver-related ailments, even in jaundice. The leaves of black nightshade plant strongly promote perspiration, when ingested in small amounts. They work to purge the bowels the next day. The juice of the herb or an ointment prepared from it is externally applied to cure certain skin problems and tumours. A decoction of the stalk, leaves, and roots of black nightshade is beneficial for wounds and cancerous sores. Its berries are poisonous, but boiling them is believed to destroy the toxic substances and make them safe to be used for preserves, jams, and pies. An infusion of the plant is used as an enema in infants suffering from abdominal upsets. Freshly prepared extract of the plant is effective in treating cirrhosis of the liver and also works as an antidote to poisoning by opium. **Culinary:** In India, black nightshade berries are grown and eaten by local people. In Ethiopia, ripe fruits of black nightshade are eaten as a snack while the leaves are also collected by women and cooked in salt water.
NUTRITIONAL VALUE
Elemental Composition of *Solanum nigrum* Leaves (100 g); Calcium: 17.33 mg; Magnesium: 247 mg; Iron: 201.3 mg Zinc: 12.91; Pottasium:42.89; Sodium: 37.19; Sulphur: 8.55
PRIMARY SOURCES
• Ojiewo CO et al 2007. Polyploidy breeding of African Nightshade. International Journal of Plant Breeding. • www.nda.co.za • http://www.iloveindia.com/indian-herbs/solanum-nigrum.html#LayAME0z4fO5Dakf.99