Edible Fynbos Plants: A Soil Types and Irrigation Regime Investigation on *Tetragonia decumbens* and *Mesembryanthemum crystallinum*

by

Chimwemwe Tembo-Phiri

Thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Sustainable Agriculture in the Faculty of AgriSciences at Stellenbosch University

Supervisor: Ms Rhoda Malgas

Co-supervisors: Dr Ethel E. Phiri

Ms Loubie C. Rusch

April 2019

Declaration

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Abstract

Fynbos' rich biodiversity has been a source of much economic activity with its beautiful wild flowers and world-famous Proteas. Additionally, the medicinal and health benefits of rooibos and honey bush have enormous market value all over the world. Despite the importance of Fynbos as a biome, the value of its edible species as agronomic resources has been neglected. A two-part study having an agronomic and social component was conducted at the Welgevallen Experimental Farm (WEF, Stellenbosch University) and the Sustainability Institute (SI, Lyndoch, Stellenbosch), respectively. The aim of the agronomic study was to determine the performance of *Tetragonia decumbens* (dune spinach) and *Mesembryanthemum crystallinum* (*sout slaai*) in relation to soil type and watering regime trials. A completely randomised design was used for the water trial having four treatments (no watering as a control, 25 %, 50 % and 80 % pot water holding capacity) and the soil trial having three treatments (dune sand from Kommetjie beach as a control, sandy soil from the SI, and loamy soil from WEF). Though the water treatments had no significant effect ($p > 0.05$) on the agronomic performance of dune spinach and *sout slaai*, the results suggested that the 25 % and 50 % water treatment levels are sufficient for growth of dune spinach and *sout slaai* when grown in the soil in which they naturally occur. Results from the soil regime trial indicated significant increases in agronomic performance of dune spinach and *sout slaai* among soil treatments, except the number of dune spinach runners and *sout slaai* leaf pairs. It was concluded that agronomic performance can be improved significantly when dune spinach and *sout slaai* are planted in more fertile sandy soils and well aerated loamy soils. For the social study, an indigenous food tasting event was organised at which a survey was administered to 24 respondents that primarily assessed their acceptance of the two edible fynbos species as alternative vegetables and nutrition sources. A cooked and raw version of each vegetable was tasted by each participant. The cooked version (*smoortjie*) of dune spinach, elicited a statistically significant median increase in acceptability compared to the, dune spinach salsa, exact $p = 0.035$. The *sout slaai smoortjie* did not generate a statistically significant median increase in acceptability compared to the *sout slaai* salsa, exact $p = 0.092$. It was found that the 'overall acceptance of dune spinach vegetable' was positively correlated to the 'overall acceptance of *sout slaai* vegetable', $r(23) = 0.504$, $p = 0.01$. There was no association between consumption intent and overall acceptance of the two indigenous vegetables, $r(23) = 0.362$, $p = 0.082$. However, there was a strong positive association between the respondent's overall acceptance of the two indigenous vegetables and their purchasing intention, $r(23) = 0.698$, $p < 0.001$. The most important reason for purchasing these indigenous vegetables that emerged was the frequency of general vegetable shopping and desire to eat the vegetables. These reasons were closely followed by the availability on the market and price of the dune spinach and *sout slaai*.

Opsomming

Fynbos se ryk biodiversiteit is ’n bron van baie ekonomiese aktiwiteite met sy pragtige veldblomme en wêreldbekende Proteas. Daarbenewens het die medisinale en gesondheidsvoordele van rooibos en heuningbos geweldige markwaarde oor die hele wêreld heen. Ten spyte van die belangrikheid van Fynbos as ’n bioom, is die waarde van sy eetbare spesies as agronomiese hulpbronne verwaarloos. ’n Tweeledige studie met beide ’n agronomiese en gemeenskap komponent is onderskeidelik by die Welgevallen proefplaas (WPP, Stellenbosch Universiteit) en die Volhoubaarheidsinstituut (VI, Lynedoch, Stellenbosch) gedoen. Die doel van die agronomiese studie was om die agronomiese prestasie van *Tetragonia decumbens* (duinspinasie) en *Mesembryanthemum crystallinum* (soutslaai) te bepaal tydens proewe met verskillende tipes grond and hoeveelhede water. ’n Ten volle lukrake ontwerp met drie behandelings en ’n kontrole is gebruik vir die waterproef; geen water as kontrole, en 25 %, 50 % en 80 % van die potgrond se waterhoudingskapasiteit. Die grondtipe proef het twee behandelings en een kontrole gehad: kus (duin) sand van Kommetjie-strand as kontrole, sandgrond van die VI en leemgrond van WPP. Alhoewel die waterbehandelings geen beduidende effek ($p > 0.05$) gehad het op die agronomiese prestasie van duinspinasie en soutslaai nie, het die resultate aangedui dat die 25 % en 50 % waterhoudingskapasiteit voldoende is vir die groei van duinspinasie en soutslaai in die grond waarop hulle natuurlik voorkom. Die grondtipe proef het ’n aansienlike toename in agronomiese prestasie van duinspinasie en soutslaai gewys. Grondanalise het aangedui dat beide spesies die vermoë het om marginale grond te verbeter. Daar is bevind dat agronomiese prestasie aansienlik verbeter kan word wanneer duinspinasie en soutslaai in meer vrugbare sanderige grond geplant word. Wat die gemeenskapstudie betref, is ’n inheemse-kos proegeleentheid gereël waar 24 respondente aan ’n opname deelgeneem het wat hoofsaaklik hul aanvaarding van die twee eetbare Fynbossoorte as alternatiewe groentes en voedingbronne beoordeel het. ’n Gekookte (smoortjie) en rou (salsa) weergawe van elke groente is geproe. Die duinspinasie smoortjie het ’n statisties beduidende mediane toename in aanvaarbaarheid in vergelyking met die duinspinasie salsa verkry, presiese $p = 0,035$. Die soutslaai smoortjie het nie ’n statisties-betekenisvolle mediane verhoging in aanvaarbaarheid in vergelyking met die soutslaai salsa genereer nie, presiese $p = 0,092$. Daar is bevind dat die ‘algehele aanvaarding van duin-spinasiegroente’ positief gekorreleer is met die ‘algehele aanvaarding van soutslaai groente’, $r(23) = 0.504$, $p = 0.01$. Daar was geen verband tussen verbruiksvoorneme en algehele aanvaarding van die twee inheemse groente nie, $r(23) = 0.362$, $p = 0.082$. Daar was egter ’n sterk positiewe verband tussen die respondent se algehele aanvaarding van die twee inheemse groente en hul aankoopvoorneme, $r(23) = 0.698$, $p < 0.001$. Die belangrikste rede vir die aankoop van hierdie inheemse groente wat na vore gekom het, was die gereëldheid van algemene groente aankope en behoefte om die groente te eet. Hierdie redes is gevolg deur die beskikbaarheid op die mark en prys van die duinspinasie en soutslaai.

Acknowledgements

I wish to express my gratitude and sincere thanks to my supervisors Ms. Rhoda Malgas, Ms. Loubie Rusch and Dr. Ethel E. Phiri for their guidance, knowledge and constructive criticism always bestowed with grace. I thank them for being wonderful role models and for setting good examples of hard work and dedication to their professions. I thank all who have contributed to the success of the Sustainable Agriculture South Africa (SASA) course offered at Stellenbosch University. Special thanks to Ms. Julia Harper for her friendship, comfort and advice.

I wish to express my sincerest thanks to my financial sponsors, the Association of Commonwealth Universities (ACU). Many thanks to my course mates Charissa, Aviwe, Jackie and Trust for their encouragement and friendship during the course.

To my husband, Dr. Temwani J. Phiri, I convey my heartfelt thanks for his love, sacrifice and unyielding support to ensure my success. To my parents and siblings, I wish to express many thanks for always having my back and for constantly praying for me.

Finally, and most of all, I thank my Lord and God, the Father of Lights who does not change like shifting shadows and from whom all good things flow. To Him be all glory, honour and praise!

The financial assistance of the Association of Commonwealth Universities (ACU) towards this research is hereby acknowledged.

Thanks to the Welgevallen Experimental Farm (WEF) for hosting my experiment.

The partnership and support of the Sustainability Institute (SI) is greatly appreciated.

Dedicated to the sweetest, kindest and most thoughtful young man I will ever meet, my friend and baby brother, Tulombe.

"Whatever happens to me, know that God is sovereign and is in control."

Till we meet again.

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Nomenclature

Acronyms and Abbreviations

CFR	Cape Floristic Region
CWF	Cape Wild Foods
CAM	Crassulacean Acid Metabolism
IK	Indigenous Knowledge
ITK	Indigenous Technical Knowledge
RPK	Rural People's Knowledge
SI	Sustainability Institute
WEF	Welgevallen Experimental Farm

Chapter 1

Introduction

1.1 Overview

Regenerative and sustainable means of utilizing scarce resources while addressing issues of food and nutrition security for a continuously increasing population, lies at the heart of many responsible conservationists. The science of agroecology provides a comprehensive way of producing or creating food in such a way that resources are utilised responsibly and replenished. Farming methods such as organic farming, conservation farming, permaculture and biodynamic farming to name a few, all have the concept of agroecology at the heart. Altieri (2018) loosely defines agroecology as being "about a more environmentally and socially sensitive approach to agriculture, one that focuses not only on production, but also on the ecological sustainability of the production system". More specifically, it "refers to the study of purely ecological phenomena within the crop field, such as predator/prey relations, or crop/weed competition". A holistic approach to agriculture that considers the ecological resources at its disposal has the power to create a mind shift that elicits appropriate and lasting adaptations and mitigations to the threats of food insecurity, malnutrition and climate change. This study addresses the potential role that two edible fynbos species indigenous to the Western Cape of South Africa, *Tetragonia decumbens* (dune spinach) and *Mesembryanthemum crystallinum* (*soutslaai*) have as agronomic resources (Victor *et al.*, 2000; Manning, 2013). Both belong to the common ice plant family (Aizoaceae) and occur along the coastal sand of the Cape Floristic Region (CFR) (Manning, 2013). For the purposes of this study, edible fynbos species is a term that will be used to describe food crops that are part of the fynbos biome. Furthermore, Cape wild foods will refer to indigenous food crops found naturally growing around the CFR but are currently not commercially domesticated or cultivated. Cape wild foods will be used interchangeably with edible fynbos.

1.2 The Role of Indigenous Knowledge in Agrobiodiversity

Indigenous Knowledge (IK) is described by Dlamini (2007) (citing Warren (1991)) as referring to:

"...traditional and local knowledge, unique to a particular culture or society, existing within and developed around specific conditions of women and men indigenous to a particular geographic area in contrast with knowledge generated within the international system of universities, research institutes and private firms".

IK exists in all areas of life and collectively refers to teachings, experience, world views, practices and innovations specific to the lifestyle of local communities and ingrained in the culture and heritage of the guardians of this information (UNEP, 1997; Battiste, 2005; Raven, 2010). This knowledge is usually ancient, has experienced the test of time and is subsequently dynamic and adaptive (Hart, 2004; Martin *et al.*, 2010; Murphy, 2011). However, this knowledge is not only restricted to local inhabitants as keen observers can also become knowledge bearers. Other terms used interchangeably with indigenous knowledge in the literature are: traditional knowledge, indigenous technical knowledge (ITK), sustainable knowledge, people's knowledge, rural people's knowledge (RPK), folk science, farmers' knowledge, cultural knowledge, and experiential knowledge, to name a few (Vorster, 2007). Agrarian societies have relied heavily on their culture and context specific knowledge for centuries to advance agricultural production. The rich biological resources provided by the landscape, coupled with knowledge of their value and usefulness, has helped push the great agricultural achievements seen today. Agricultural practices such as the utilization of natural pest and weed control, inter-cropping and rotation of specific plants to increase yields and food quality are just some of the few outcomes of the application of indigenous knowledge within agriculture. As a result, indigenous knowledge application in agriculture has relied heavily on biodiversity.

Agrobiodiversity (or agricultural biodiversity) can be described as "the use of the variety of genetic resources available in the ecosystem and the means through which this biological diversity can be utilised to farm sustainably" (Thrupp, 2000). More recently, Zimmerer (2010) defined agrobiodiversity as "species and varieties of crops and livestock and their wild relatives, including weeds and interacting biota, modified through the ongoing process of farmer-based domestication and adaptation". While both definitions emphasise the natural science aspect of agrobiodiversity, both authors also refer to the complexity around the concept that cannot be isolated from the social, cultural and politically specific environments it exists in. Applying ecological principles in agricultural systems also gives rise to the concept of agroecology. Altieri (2018) refers to agroecology as agronomic knowledge that incorporates the use of ecological resources to build a natural resilience towards risks caused by environmental and economic mechanisms in order that productivity is maintained within the limits of regionally available resources. Indigenous knowledge in agroecology is "relevant for the conservation and sustainable use of biological biodiversity" (UNEP, 1998). As a result, traditional ecological knowledge (TEK) is increasingly gaining the same value has scientific knowledge particularly as the threats of climate change and food insecurity continue to affect the globe (Thrupp, 2000; Martin *et al.*, 2010; Turner *et al.*, 2011; Mauro *et al.*, 2015; Hathaway, 2016). For this reason agrobiodiversity is one of the principles of agroecology with IK linking the two. Subsequently, previously neglected and suppressed indigenous knowledge has re-emerged as being important for sustainable mitigation strategies for resilience building particularly in agriculture (Woodley, 1991; Warren, 1990; Bollig and Schulte, 1999; Hart, 2004).

Indigenous useful plant species are valuable components of biodiversity and in agricultural settings, they are essential for agrobiodiversity. This is especially true in systems where wild crop relatives form part of the agrobiodiversity in and around areas where their domesticated counterparts are produced. For example, in the use of genetically diverse traditional maize and sorgham landraces to counter abiotic stresses by farmers in Mexico and India respectively (Pandravada *et al.*, 2013; Hellin *et al.*, 2014). Agricultural systems that promote greater biodiversity have proven to be more resilient to unpredictable weather events such as droughts and floods, sporadic or marginal rainfall and pest infestation (Dlamini, 2007; Schutter, 2009; National Research Council, 2010; Summaries, 2010; Williams *et al.*, 2018). Moreover, resource poor farmers who tend to invest in growing more than one crop are also likely to be more food secure, enjoy a more diverse diet, better nutrition and more expendable cash as they are not dependent on one crop to provide and sustenance (Phiri, 2005; Dlamini, 2007; Aliber, 2009; Chivenge *et al.*, 2015). Furthermore, agrobiodversity provides greater food and nutrition security for resource-poor households (Mavengahama, 2013; Ochieng *et al.*, 2016; Gido *et al.*, 2017). Keeping in mind that the benefits of agrobiodiversity are usually context dependent, a study by Williams *et al.* (2018) showed that market-oriented households had higher species richness in their home gardens thus increasing food and nutrition security for those households. This corresponds with a study by (Vorster, 2007) which showed that indigenous foods were mostly restricted to household consumption. More diversity in agricultural produce through the utilisation of indigenous vegetables can also be a source of income for growers in communities where there is consumer demand. This is shown in studies conducted in Kenya, Zambia and Indonesia (Dahlia *et al.*, 2012; Muhanji *et al.*, 2011; Mshenga *et al.*, 2016; Okello *et al.*, 2015; Chivandi *et al.*, 2015).

Indigenous, traditional or wild food crops have been described as those that naturally grow wild or were introduced into the country and are now considered naturalised food crops (DAFF, 2013). These native food crops occur in specific parts of the country or region and they have tender leaves, flowers, young shoots, and fruits, that can be consumed (Jansen van Rensburg *et al.*, 2007). Traditional food crops gathered, harvested or cultivated for food within a particular region have been shown to contribute significantly to food security and nutritional requirements (Vorster, 2007; Mavengahama *et al.*, 2013; Ndwandwe, 2013; Bvenura and Afolayan, 2015; Aworh, 2015; Satter *et al.*, 2016). This is especially true in rural and vulnerable communities that are exposed to harsh environmental and social conditions. Since IK is deeply tied to the culture of those who hold the knowledge, understanding the knowledge systems would also give researchers and other interested parties an idea of what would be culturally and locally appropriate interventions.

1.3 The Role of Indigenous Vegetables in Addressing Food Security

Food security is one of the ultimate goals of encouraging the adoption of agroecological methods of production. According to the World Food Summit of 1996 (as cited by Ericksen (2008)) food security refers to “when all people, always, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life”. This definition of food security already assumes that the process of getting the food from farm to table will provide safe and nutritious food in enough quantities. Meanwhile, food insecurity is closely tied to poverty particularly in the global south. Poverty can be defined as "the lack of [food] resources necessary for survival" (Richmond, 2007). A basic element of survival is to have the ability to access food for sustenance. Consequently, households that are poverty stricken are most often food insecure and hungry.

A survey by SSA (2017) revealed that poverty in South Africa has been on the rise with the majority of the population (over 60 %) living in extreme poverty (less than ZAR 600/month) and food insecure. At household level, 40 % of South Africans were vulnerable to poverty and hunger. The Western Cape and Gauteng showed a lower incidence of poverty between 2006 and 2015 when compared to the other provinces in Figure 1.1. However, 37.1 % of the population in the Western Cape were still living in poverty by 2015 (SSA, 2017). At household level, 25.3 % of South Africans were vulnerable to poverty. Amongst the most vulnerable were children, females, the elderly, and dark-skinned Africans (SSA, 2017). To illustrate, a study conducted by Modiwa (2015) in the Eden District of the Western Cape showed that female headed households were more likely to be food insecure than male headed households. In addition, a previous study showed that in as much as food insecurity halved for both rural and urban communities in South Africa between 1990 and 2008, the number of households that would not be able to resist food insecurity did not change (Labadarios et al., 2011). The most vulnerable households where in the predominantly rural provinces, i.e. the Northern Cape, Eastern Cape, Limpopo, and North-West provinces (Labadarios *et al.*, 2011). Over 85 % of rural households failed to afford food that would supply basic dietary energy needs (Jacobs, 2009). The high cost of energy and food, poor economic growth, lower prices for local agricultural products and consequent rise in unemployment for farm dependent workers has pushed many households into further poverty and debt (SSA, 2017).

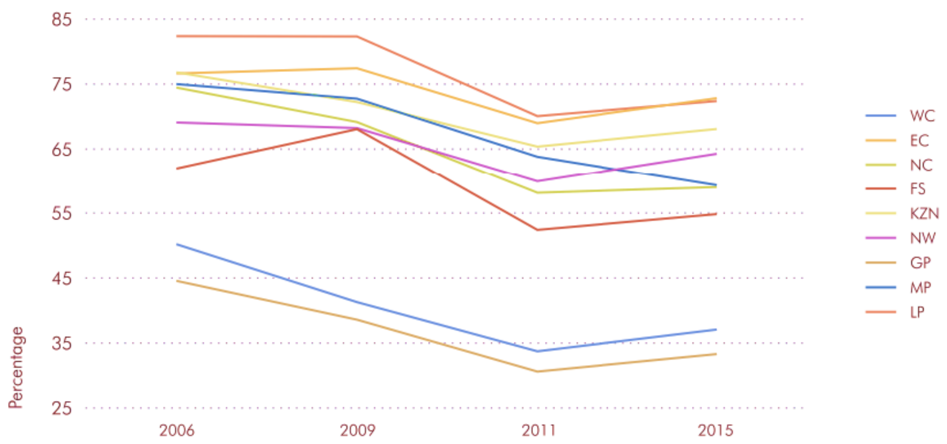

Figure 1.1: Poverty headcount by province (SSA, 2017)

The use and cultivation of indigenous edible species present a unique opportunity to addressing the dual issues of mitigating food insecurity and poverty (Bvenura and Afolayan, 2015).

Indigenous plant species are typically well adapted to their natural environment and grow independently in water scarce conditions (Slabbert *et al.*, 2004; Vorster, 2007; Mbatha, 2010). They are characteristic of being climate adaptable foods that consequently require low input and are independent of agro-chemicals (Hart, 2011; Hellin *et al.*, 2014; Chivenge *et al.*, 2015). The added ability of indigenous food crops to thrive in poor soils with no additional nutrients can encourage the adoption and utilization of these species (Mills and Fey, 2004; Deynze *et al.*, 2018; Van Wyk and Gericke, 2017). Out of 100 000 species of edible plants only 30 plant species are utilized as sources of energy globally (Durst and Bayasgalanbat, 2014). Southern Africa alone, has over 30 000 species of useful plants, while South Africa has recorded at least 1703 species of edible plants, with 103 wild vegetables recorded outside of the Western Cape (Manning, 2013; Bvenura and Afolayan, 2015; Van Wyk and Gericke, 2017). The use and acquired taste for local edible species can create a local market that will promote local production and may potentially aid in providing a source of livelihood as the local economy is boosted (Chivandi *et al.*, 2015). This can only happen with a respectful and mutually beneficial knowledge sharing relationship among communities, farmers, researchers and local governments.

Options for local communities and farmers to secure sustainable food sources can help in establishing food systems that are appropriate for each context. High levels of food insecurity lead to poor nutritional status. The utilisation of indigenous wild edible plants could address the challenges of food security and the nutritional deficits that stem from it. Additionally, applied agrobioversity has a direct link to food security as well as nutrition and health (Heywood, 2011). Well-applied agroecological principles can make use of waste material to generate more energy for production, sequester larger carbon quantities, reduce the use of chemicals by utilizing beneficial plants and insects while responsibly utilization fresh water resources (Hathaway, 2016).

1.4 Statement of the Problem

The Cape Floristic Region's (CFR) Fynbos Biome has a rich heritage of research with regards to its flora's biological, medicinal and health benefits, aesthetic, and eco-tourism value (Reinten and Coetzee, 2002; Conradie and Knoesen, 2010; Snijman, 2013). However, given its importance as a biome in South Africa, the Cape fynbos has been neglected with regards to the value of its edible species as agronomic resources. Literature on native plants outside the Western Cape has shown that indigenous food crops tend to be hardy and more tolerant of pests and diseases when compared to exotic species (Venter *et al.*, 2007; DAFF, 2013; Mavengahama *et al.*, 2013; Ribeiro, 2017). Having been acclimatised to their localised environments they are robust and adaptable to climate change situations (Vorster, 2007). Quick growth with little input such as labour, water and nutrients are some of the marked traits of indigenous crops (Mbatha, 2010; Mavengahama, 2013; Maseko, 2014; Ribeiro, 2017). Moreover, some indigenous food crops have been recorded to be high in nutrients though not always higher than more conventional vegetables (Odhav *et al.*, 2007; Uusiku *et al.*, 2010; Mavengahama *et al.*, 2014; Bvenura and Afolayan, 2015). These locally adapted species present opportunities for addressing issues of undernourishment and micronutrient deficiencies while responsibly utilizing scarce and limited resources.

In spite of their benefits, indigenous crops in some provinces of South Africa are considered to be weeds in mainstream farming and are associated with backward knowledge (Vorster, 2007; Jansen van Rensburg *et al.*, 2007). In addition, changing taste of preference in favour of westernised diets and the perception of indigenous foods as low status food discourages their adoption particularly by younger generations (Vorster, 2007; Matenge *et al.*, 2012; Mavengahama, 2013). It has been reported that the lack of diversity in the preparation of some of the indigenous wild vegetables leads to monotony and lack of interest in them as food (Vorster, 2007; Jansen van Rensburg *et al.*, 2007). Additionally, disinterest in acquiring knowledge of beneficial wild foods and ignorance regarding nutritive value has contributed to the decline of indigenous vegetable use (Vorster, 2007).
Furthermore, while much research has gone into some species of the CFR and a few other indigenous plants from the rest of South Africa, technological and academic focus has been directed towards enhancing already commercially orientated food crops more suitable for modern agricultural practices (Reinten and Coetzee, 2002). Consequently, genetic properties of indigenous vegetables have not yet been characterised, evaluated, or stored, which has also increased the threat to loss of knowledge relating to indigenous crops biodiversity (Mavengahama, 2013; Bvenura and Afolayan, 2015). Although some limited work has been conducted on the breeding and improvement of selected indigenous vegetables, there is still limited information regarding the technical production knowledge of many indigenous crops (Slabbert *et al.*, 2004). In addition, the lack of economic incentives promoting indigenous vegetables has hindered quick progress in this area (Phiri, 2005).

The CFR, specifically, accounts for 10 % of the useful plants in Southern Africa and this accounts for its rich biodiversity (Mucina and Rutherford, 2006). While much work has gone into classifying species in the CFR, with over 9000 taxa within the region, more time would be needed to identify and understand more of the species' ecology (Rebelo *et al.*, 2006). Consequently, the use and benefits of edible species in the CFR have not yet been fully recognised though there is some literature around edible plants in this region (Van Wyk and Gericke, 2017; Manning, 2013; Coetzee, 2010; Van der Merwe and De Villiers, 2014; Notten, 2015; Coetzee, 2015; De Vynck *et al.*, 2016). Except for rooibos, honeybush, waterblommetjies and proteas that are widely known and commercially accepted, not many food species are as widely utilised or known.

As there is little work that has been done on the cultivation of wild edible species in the Western Cape, it must be stated at this point that some ground work has been done by Ms. Loubie Rusch. A wild food innovator and slow food activist in Cape Town, South Africa. In a non-academic investigation, she explored the potential cultivation of at least eight coastal indigenous edible species. This research was carried out at the Cape wild food garden in Khayalitsha in 2016 and has since ended. It was funded by the Sustainability Institute in Lynedoch, Stellenbosh and the report is available upon request. As a result of this study and her activism, a few non-peer reviewed articles have been written by Black (2015); Schumann (2015); Food & the Fabulous (2016); Stone (2016); Grangeon (2018) and Mckeown (2017). These articles and the report from the Khayalitsha garden trial are referred to throughout this thesis where appropriate. Additionally, references with websites have been provided accordingly.

1.5 Justification

The purpose of this study is to contribute to the knowledge base of two indigenous wild vegetables in the Western Cape's fynbos with regards to their agronomic potential to broaden the food basket to sustainably meet food and nutrition needs. Before the 1600s, indigenous people in the Western Cape foraged many of the indigenous edible plants (De Vynck *et al.*, 2016). To the best of our knowledge and what is recorded in literature, edible and other useful species in the Western Cape were not cultivated by previous hunter-gatherer communities (Schrire, 1980; Testart, 1988; Viljoen, 2006; Layton and Rowley-Conwy, 2013; La Croix, 2018). Colonialization, loss of land and restriction of access to land belonging to indigenous people resulted in an erosion of the knowledge around these foods. Descendents of previous hunter-gatherer and nomadic herding groups are currently few and marginalised (Cavanagh, 2013; La Croix, 2018). Consequently, current communities living in the Western Cape are disconnected from their landscapes and the food it generates (De Vynck *et al.*, 2016). Accordingly, there is much knowledge to be revived and rediscovered around wild edible plants that were previously foraged. The task is all the more important as older knowledge-holders age and pass on, sometimes with that knowledge not having been handed down.

Wild edible species can be a potential sustainable source of food and income in resource-poor and agrarian communities. However, foraging alone will not be sustainable as many of the fynbos species suitable for human consumption are critically endangered (Conradie and Knoesen, 2010; Schumann, 2015; Stone, 2016; Grangeon, 2018). In response to concerns of the potential genetic erosion that excessive foraging may bring, Rusch (2016) explored the ease of cultivation of at least eight coastal indigenous edible species. The goal of her research was to explore an easier and sustainable means of accessing the wild species by propagating them. It is out of this foundation that the current study focused on two edible fynbos species *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*). Both species belong to the family Aizoaceae also referred to as the common ice plant family. Being leafy in nature, these vegetables can serve as a sustainable source of nutrition and livelihood if introduced into the local food system. In addition to this, the rise of various food innovators and initiatives on rediscovering local wild foods in the Western Cape, motivates the need for knowledge generation and sharing. This collection of information is imperative to providing locally relevant solutions to the problem of food insecurity.

The significance of the research is that it described the agronomy of these vegetables under selected conditions. The study investigated their interaction with different irrigation regimes for potential large scale production in a landscape threatened by long periods of drought which are becoming more difficult to predict under climate change conditions (Agenbag, 2006). Furthermore, the dune spinach and *soutslaai* were grown under controlled conditions in late summer even though in nature they respond to winter rain. Both plants respond to water even during dry conditions but before fruiting so this investigation adds to knowledge of how these plants would perform under cultivation outside their winter growing season. Shifts in rainfall patterns leading to longer dry conditions necessitates pushing the boundaries on plants that show potential to be productive all year round. Moreover, encouraging and strengthening people's abilities to cultivate food for themselves can help empower communities to become food secure and maintain a healthy balanced diet. Ultimately, the cultivation of edible indigenous vegetables may also aid in avoiding biodiversity erosion, especially as peri-urban and urban communities continue to expand.

1.6 Aims and Objectives

The aim of the study was to determine the agronomic performance of *T. decumbens* and *M. crystallinum*, two wild edible plant species in the Western Cape fynbos. The specific objectives of the research were to:

- Investigate the effect of water and soil regimes on biomass accumulation, growth and physiological responses of dune spinach and *soutslaai*.
- Explore the general perceptions, acceptability and intended future consumption of the wild vegetables

1.7 Research Questions

1. What are the differences in agronomic performance of two edible fynbos species when subjected to varying water and soil treatments?
2. What are the differences in potential consumer acceptance and consequent adoption of the two edible fynbos species?

1.8 Conclusion

This chapter provides an overview of the nature of the research. The role of indigenous knowledge and biodiversity in agriculture and subsequently food security are discussed. It provides a description of the problems that need to be addressed and some of the current gaps in scientific literature and research regarding two indigenous edible fynbos species dune spinach (*T. decumbens*) and *soutslaai* (*M. crystallinum*) that are indigenous to the Western Cape. The chapter then provides the rationale for the research and subsequently gives the aim and objectives of the study.

Chapter 2 gives a detailed description of *T. decumbens* and *M. crystallinum* and gives an overview of their ecological and social context. Their potential use and agronomic performance is also highlighted.

Chapter 3 presents the agronomic section of the study. A quantitative investigation on the agronomic performance of *T. decumbens* and *M. crystallinum* is presented. The research method is described and subsequent results are discussed. Because the two species are investigated separately and two trials (water and soil regime trials) are carried out on each species, water regime trial results are reported first for each species then the soil regime trial results are reported subsequently.

Chapter 4 describes a survey that was carried out at the Sustainability Institute (SI), Lynedoch. The qualitative research method is provided and the results of a food tasting event and survey of the two species, dune spinach (*T. decumbens*) and *soutslaai* (*M. crystallinum*), are discussed. Final conclusions and recommendations are given in Chapter 5.

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Chapter 2

Literature Review

Keywords: Edible fynbos; *Tetragonia decumbens*, *Mesembryanthemum crystallinum*

2.1 Overview

The goal of this chapter is to explore the available literature on the ecology, availability and agronomic potential of two edible fynbos plant species, *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*), in the Western Cape Province of South Africa. Additionally, this chapter will investigate literature around consumer attitudes and adoption of indigenous edible species. Edible fynbos species is a term that will be used to describe food crops that are part of the fynbos biome. Furthermore, for the purposes of this study, Cape wild foods will refer to indigenous food crops found naturally growing around the CFR but are currently not commercially domesticated or cultivated. Cape wild foods will be used interchangeably with edible fynbos. The chapter seeks to probe any gaps in literature regarding the agronomic use of edible species in the Western Cape in addressing issues of food security, climate change, and responsible resource management and consumption.

The responsible utilisation of all resources for the benefit of the next generations is vital for the survival of all living things, and food, in all its various forms, plays a major role in this. However, food and its journey from farm to table, are embedded in a complex system in which environmental, economic and socio-cultural considerations are only the beginning (Ericksen, 2008). Wild vegetables have always been a significant source of food and nutrition security for rural communities (Ndwandwe, 2013; Durst and Bayasgalanbat, 2014; Chivenge *et al.*, 2015). So far, agriculture in the Western Cape has focused on utilizing the Mediterranean climate and winter rainfall for horticulture farming thus producing fruits and grapes primarily. As previous indigenous communities, now marginalised, in the Western Cape foraged for wild foods, most current locals have experienced a disconnect from their landscapes with regards to edible species indigenous to the Cape (Schrire, 1980; De Vynck *et al.*, 2016*a*; Stone, 2016; Lindow, 2017; La Croix, 2018). In other provinces of South Africa where communities are more knowledgeable of the wild edible and useful species their landscapes provide, women and children are still most at risk to food insecurity and hunger (SSA, 2017). A national food consumption study by Labadarios *et al.* (2005) revealed that at least 1 out of 5 children in South Africa experience stunting (chronic undernourishment) as a symptom of micronutrient deficiency. Furthermore, one out of ten children where underweight with children from informal urban households being the most affected. Six years after a mandatory fortification of food provided by the National School Nutrition Program (NSNP) was motivated for by the previous study, a systematic search of national surveys by (Labadarios *et al.*, 2011) showed that while food insecurity in South Africa had halved between the years 1999 and 2008, stunting was still a common problem amongst children. Further analysis showed that the stunting and below average body weight was positively related to dietary diversity. If included into these feeding programs in attractive forms, wild vegetables can address micronutrient deficiencies that cause stunting in children while further lowering overall food insecurity and alleviating temporal hunger. Promotion of the consumption of these vegetables in schools can also create a market for farmers which will encourage a more sustainable level of agricultural production and improve livelihoods.

The role of indigenous edible species in sustainable farming practices and consumption can not be overstated particularly considering the ever increasing global population and extreme environmental changes. Hence, linking indigenous edible species, responsible use of natural resources and consumer willingness to adopt more sustainable food sources can address many of the Sustainable Development Goals (SDGs) (FAO, 2017). The use of indigenous edible foods particularly in areas most vulnerable to climate change effects can contribute effectively to at least seven of the SDGs, which include poverty alleviation, zero hunger, good health and well-being, responsible consumption and production, sustainable cities and communities, climate action, and creating partnerships to achieve these goals.

2.2 Background to Edible Fynbos Species

The Southernmost tip of Africa is home to an area occupying over 90 000 km^2 called the Cape Floristic Region (CFR) (Goldblatt, 1997; Manning, 2013). The CFR is recognised as the smallest of the six Floral Kingdoms of the world that runs from Clanwilliam in the north of the Western Cape to Port Elizabeth in the east of the Eastern Cape, as shown in Figure 2.1. The CFR supports the richest level of botanical diversity per unit area with 67 % of its area occupied by fynbos vegetation (Rebelo *et al.*, 2006; Manning, 2013; Valente *et al.*, 2014). Fynbos has over 9000 species of flowering plants and 70 % of these plant species are unique and endemic (Goldblatt, 1997; Van Rooyen and Janssen, 2010; Segobola *et al.*, 2018). Additionally, the biodiversity and ecosystem services of the Fynbos Biome are greatly threatened by agricultural activities such as orchards, vineyards, animal husbandry, and uncontrolled foraging (Willis, 1994; Victor *et al.*, 2000; Honig *et al.*, 2015). Other threats include urban infrastructure and development, as well as the challenges of managing alien invasive species (Roura-Pascual *et al.*, 2009; Gaertner *et al.*, 2012). Even though many areas have been conserved to preserve numerous fynbos species, vast tracts of land in the fynbos are being used to grow high-input crops, which may soon prove to be unsustainable in the face of growing consumption and use of resources, and the vagaries of climate change.

The CFR is home to the Fynbos and Succulent Karoo Biomes and three vegetation types within the Fynbos Biome; viz. fynbos, renosterveld and strandveld (Snijman, 2013). Fynbos, which is the point of interest in this research, was first coined by John Nobel in 1868 and formally used by an ecologist called John Brews in the early 20th century (Manning, 2013). Pronounced as "feinbos" it means "fine bush" (Rebelo *et al.*, 2006). It is defined by 'an evergreen, hard-leafed shrubland occurring on nutrient-poor soils, especially derived from heavily leached sandstones

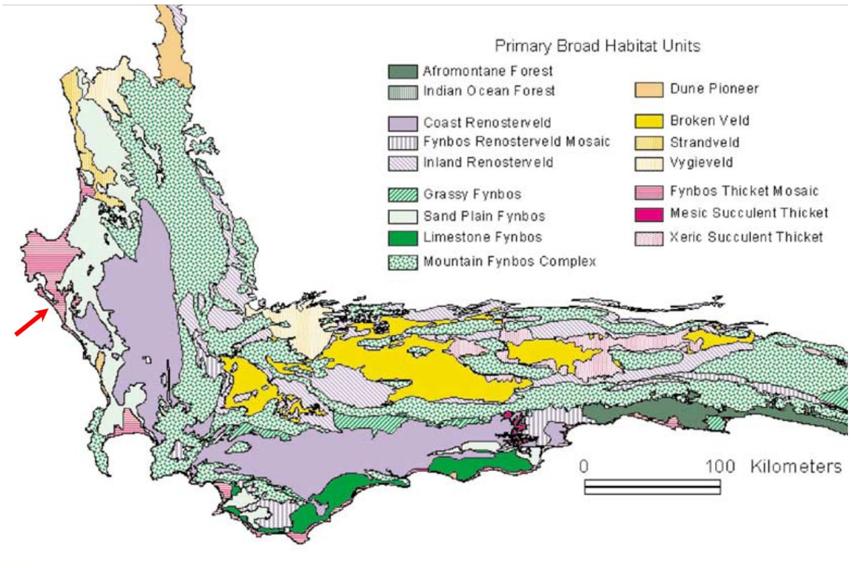

Figure 2.1: Map of the major habitats of the Cape Floristic Region (Rim of Africa Multimedia Trail Journal, 2013)

or limestones; dominated by small and leathery-leafed shrubs associated with evergreen, grass-like perennials; and comprising especially members of plans groups that are characteristic of the Cape Floristic Region' (Mucina and Rutherford, 2006; Rebelo *et al.*, 2006; Abanda *et al.*, 2011; Manning, 2013; Coetsee *et al.*, 2015; Segobola *et al.*, 2018). At least a third of the shrubby species, most of which to not exceed 0.5m in length and thus considered dwarf succulents, belong to the common ice plant family (Snijman, 2013). As a vegetation, fynbos is characterised by the presence of *Restio* spp., which are evergreen graminoids of the Restionaceae family (320 species), ericoid fine leaved shrubs, which are of the Ericaceae family (670 species), and *proteoid* shrubs from the Proteaceae family (330 species) (Manning, 2013). *Citrus* (273 species) and *Phylica* (137) are the third and fourth largest genera in the Fynbos Biome (Helme and Schaminee, 2012).

The Fynbos Biome is most commonly known for its biodiversity, aesthetic and medicinal value (Reinten and Coetzee, 2002; Conradie and Knoesen, 2010; Kokotkiewicz and Luczkiewicz, 2013). Since the discovery of *Protea neriifolia* in the 17^{th} century by the crew of a Dutch East Indiaman, much focus has been placed on developing the aesthetic and eco-tourism value of fynbos. Currently, fresh flower industry yielding over 5 million stems for export for *Protea* flowers alone in 2016/2017 (Van Zyl and Goosen, 2017). In addition, many species have been known to have medicinal qualities and, consequently, there is extensive interest and investment in fynbos for its medicinal and health benefits in tea products such as Rooibos (*Aspalathus linearis*) and Honeybush (*Cyclopia spp.*) (Le Maitre *et al.*, 1997; Joubert and de Beer, 2011; Kokotkiewicz and Luczkiewicz, 2013).

Even though the biodiversity of Fynbos Biome offers different services to various stakeholders, conserving the species richness and ecosystem services has never been disputed within the scientific community (Le Maitre *et al.*, 1997; Conradie and Knoesen, 2010; Joubert and de Beer, 2011; Honig *et al.*, 2015). The significance of the Fynbos Biome has been valued at R 9.6 billion per year on the marine environment's ecosystem alone (BirdLife South Africa, 2016). Moreover, the benefits of ecosystem services such as stabilising dunes, water filtration, carbon sequestration, and flood buffering have been enjoyed (Costanza *et al.*, 2017). As such, the South African Biodiversity Institute (SANBI) has established conservation initiatives and incentives in recognition of the need to preserve this richly diverse biome. One such initiative is the Biodiversity Stewardship Program that encourages land owners to use sustainable farming and land management practices to preserve the endemic species on their properties (Le Maitre *et al.*, 1997; BirdLife South Africa, 2016).

With the CFR having the highest known concentration of plant species, the vast knowledge of the usefulness of the edible species must be gathered and explored (De Vynck *et al.*, 2016*b*). Furthermore, to develop more sustainable food systems that are socially and culturally relevant, it is imperative that various stakeholders and communities pool resources and knowledge to create a database of information on wild foods indigenous to the Western Cape (Rusch, 2016; Lindow, 2017; Mckeown, 2017). This should serve to provide readily accessible knowledge on these alternative food sources and their agronomic importance for potential mainstream focus. In turn, this will mitigate issues of biodiversity conservation, undernourishment, food security, and climate variability.

The focus of the study was limited to two species that occur along the arid coastal areas, dune spinach (*T. decumbens*) and *soutslaai* (*M. crystallinum*). Both are leafy edible fynbos species that occur along the Strandveld (also called beach vegetation). Amongst the Strandveld are the succulent, low lying broad leafed shrubbery of the *Mesembryanthemum* and *Tetragonia* genera that are part of the Lambert's Bay, Saldanha Flats, Saldanha Limestone, Overberg Dune, and Cape Flats Dune Strandveld (Rebelo *et al.*, 2006). Figure 2.2 shows a map of the distribution of the common ice plant family across the Western Cape.

2.3 Cape Wild Foods

Cape wild foods is a term that has been used to specifically refer to food crops that are indigenous to the CFR (Rusch, 2016), but is certainly not limited to only fynbos species. Aside from dune spinach and *soutslaai* there are a few other commonly used wild vegetables that are not known as edible fynbos species. *Oxalis pes-caprae*, also known as wild sorrel or *suring* in Afrikaans, is a vitamin C rich fynbos plant whose leaves, flowers and roots can be eaten raw or cooked. The edible flowers of *Gasteria* sp., known as ox-tongue or *beestong*, and *Geranium incanum*, also known as carpet geranium or *amarabossie*, are used as culinary decorations and can be eaten raw or cooked. Moreover, carpet geranium can be crystallised to be used in pudding and cake (Manning, 2013; Notten, 2015). Both species are used in herbal teas and have also been reported to be used for treating venereal diseases and bladder infections (Van Wyk and Gericke, 2017). *Tulbaghia vio-lacea* (wild garlic) and *Hypoestes aristata* (ribbon bush) are also examples of plants whose young leaves and flowers can be eaten fresh or cooked (Not-

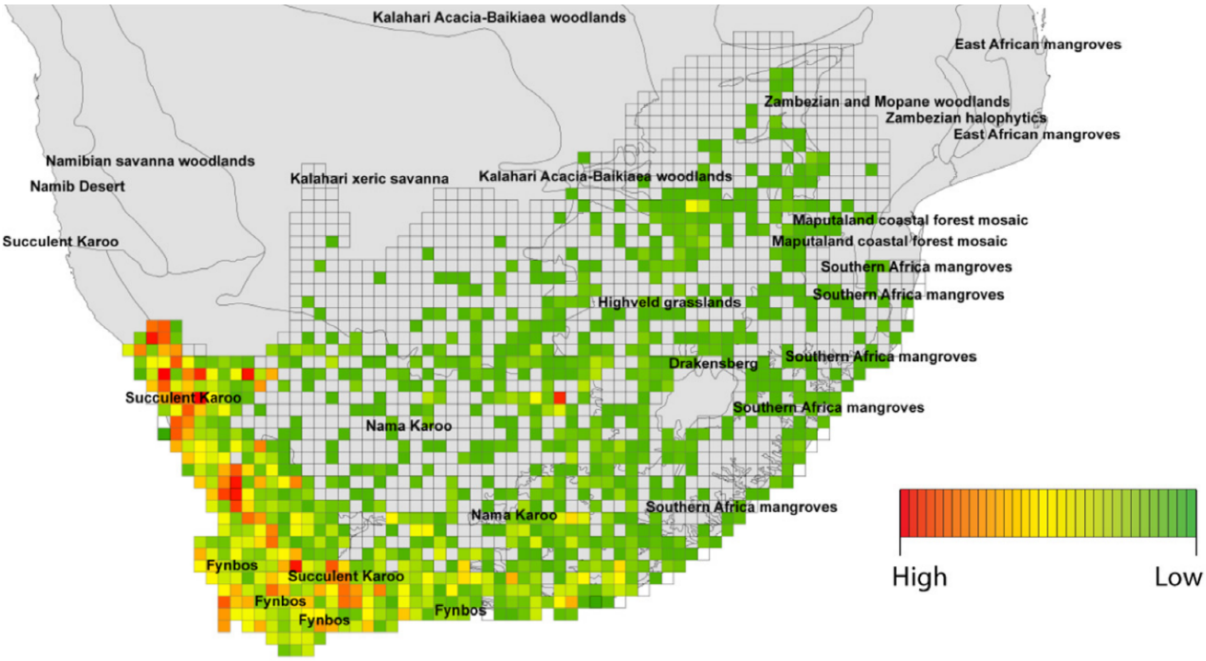

Figure 2.2: Map of the distribution of the Ice plant family (Aizoaceae) which includes both dune spinach and *soutslaai* (Valente *et al.*, 2014)

ten, 2015). Other examples of edible indigenous food species are documented in books such as those written by (Coetzee, 2010; Van der Merwe and De Villiers, 2014; Coetzee, 2015; Van Wyk and Gericke, 2017).

T. decumbens and *M. crystallinum* both belong to the Aizoaceae or common ice plant family, class: Angiosperms, order: Caryophyllales (Manning, 2013). The Aizoaceae family is one of the largest families in the Cape Flora (Goldblatt, 1997). According to Snijman (2013), there are 658 shrubby species that belong to the Aizoaceae family, most of which are dwarf succulents. Both dune spinach and *soutslaai* occur in the coastal sands of the CFR from southern Namibia, Gariep, Namaqualand Sandveld, the Core Cape Subregion, as well as the Eastern Cape (Victor *et al.*, 2000; Snijman, 2013; Manning, 2013; De Vynck *et al.*, 2016*a*).

2.3.1 *Tetragonia decumbens Mill* (Dune Spinach)

Tetragonia decumbens Mill, also called dune spinach or *duinespinasie* in Afrikaans, belongs to the genus *Tetragonia* also called kinkelbos, klapperbrak and sea spinach. It is native to Africa, Australia, South America and Asia. Of the Tetragonia genus, about 67 species are endemic in Southern Africa. *Tetragonia decumbens* is an endemic and sprawling perennial shrub with long fibrous roots as displayed in Figures 2.3 and 2.4. Dune spinach has sprawling branches (runners) that can go up to 1 m long. It has papillose-hirsute, oblong or lance-shaped fleshy leaves that feel hairy to the touch as seen in Figure 2.5 (Manning, 2013; Snijman, 2013). The glistening leaves have a shiny and warty appearance due to small shiny epidermal bladder cells[1]

[1]A bladder cell is a specialised leaf structure, also termed a salt gland, that stores water and salt ions secreted by a mature halophytic plant under stress (Adams *et al.*, 1998; Chiang *et al.*, 2016; Kiani-Pouya *et al.*, 2017).

(Watkins *et al.*, 1988; Snijman, 2013; Manning, 2013; Van Wyk and Gericke, 2017). Consequently, dune spinach has been referred to as having the texture of a 'cat's tongue' (Black, 2015). Figure 2.5 illustrates dune spinach in flowers with small, branched auxiliary yellow flowers that turn into stiff four-winged fruit (Manning, 2013; Van Wyk and Gericke, 2017). Flowering occurs between August and November with seeds that vary in size and have a brown hard outer casing with distinct rigid wings when dry as shown in Figure 2.6 (Snijman, 2013). It is a pioneer plant whose low growing hardy nature covers dunes like a dark green herbaceous 'edible carpet' as illustrated in Figure 2.4 (Rebelo *et al.*, 2006; Rusch, 2016; Van Wyk and Gericke, 2017). Some uses of dune spinach include stabilizing the sand dunes along the coast, acting as a seed trap and generating organic matter (Van Wyk and Gericke, 2017).

Figure 2.3: Rainfed wild dune spinach at Betty's Bay, Western Cape, South Africa

Figure 2.4: Rainfed cultivated dune spinach at the Sustainability Institute, Lynedoch, Western Cape, South Africa

Figure 2.5: Dune spinach flowers (Happy By Nature, 2018)

Figure 2.6: Dune spinach seed

While most plant species cannot complete their life cycle in saline conditions, dune spinach is very tolerant to saline (salt) conditions occuring along the coastal sands in which it occurs (Forrester, 2003; Rebelo *et al.*, 2006). In spite of this, it has been found that other *Tetragonia spp* are not only restricted to saline conditions (Watkins *et al.*, 1988). The ability of dune spinach to withstand high salt conditions and accumulate salt in its bladder cells suggest that dune spinach may be a halophyte. Admittedly, literature is not clear as to what type of salt tolerant plant dune spinach is. Nonetheless, based on conclusions by Watkins *et al.* (1988) and Yousif *et al.* (2010) on its relatives, the climbing New Zealand spinach (*Tetragonia trigyna*) and New

Zealand spinach (*Tetragonia tetragonioides*) respectively, the Western Cape dune spinach may be a marginal halophyte or semi-halophyte. Halophytes are more adapted to hot, dry and saline conditions as is the case in semi-arid conditions (Bartels *et al.*, 2005; Yousif *et al.*, 2010).

The use of halophytic plants for food production could be a climate change adaptation strategy as fresh water continues to become scarce and the rains, particularly in Sub-Saharan African, become more sporadic (Glenn *et al.*, 1999; Bartels *et al.*, 2005). Consequently, minimal water usage to produce nutritious leafy vegetables can help reduce irrigation costs of growing plants that are not salt tolerant. Based on the conclusion by Watkins *et al.* (1988), dune spinach is able to utilize either the C_4 or crassulacean acid metabolism (CAM)[2] cycle to increase water use efficiency and maximise the use of carbon dioxide to produce plant carbohydrates under biotic and abiotic stresses (Atia *et al.*, 2014). This adaptation strategy of most halophytes to essential to combating extreme temperature changes and dry conditions (Winter and Holtum, 2007; Atia *et al.*, 2014). Rusch (2016) observed that dune spinach runners remain lush during the winter rains and when watered outside of season then go dormant in water scarce conditions. The plant survives by its runners that die back into woody stalks and reducing leaf area during summer to increase water-use efficiency (Rusch, 2016; Lindow, 2017). There is potential for extended harvesting in summer if irrigated and is best propagated from cuttings (Rusch, 2016).

2.3.2 *Mesembryanthemum crystallinum* (*SoutSlaai*)

Mesembryanthemum crystallinum, also called *brakslaai* in Afrikaans has shared the name *soutslaai* with another similar species *Mesembryanthemum guerichianum* (Snijman, 2013). According to Snijman (2013), there are 77 *Mesembryanthemum spp.* in the dry parts of Southern Africa of which 41 are endemic. Similar to dune spinach, *soutslaai* is a winter plant that occurs along coastal sands from southwestern Angola through the Cape Peninsula (Western Cape) to the Eastern Cape (Rebelo *et al.*, 2006; Snijman, 2013), but also spreads inland into the Cederberg and the Karoo (Manning, 2013). Unlike dune spinach, *soutslaai* is an annual prostrate plant with an appearance of a rosette of leaves, (Snijman, 2013). Figures 2.7 shows how *soutslaai* has large edible oval or paddle shaped succulent leaves and stems that become smaller with age (Adams *et al.*, 1998; Manning, 2013; Snijman, 2013). The leaves are also covered with distinct epidermal bladder cells that look like crystals in daylight as shown in Figures 2.8 and 2.9. These cells are more pronounced in *soutslaai* than dune spinach and become larger as the plant matures giving a shiny appearance, hence the name ice plant (Adams *et al.*, 1998; Manning, 2013). The plants bear white or pinkish flowers, between October and December, that develop into fleshy edible fruit segmented into five parts (Snijman, 2013; Manning, 2013). At the start of the rainfall season, *soutslaai* disperses its minute seed out of the capsules (Adams *et al.*, 1998). Seeds are displayed in Figure 2.10. Rusch (2016) observed that plants of *soutslaai* sprout all year round and grow well in most soils. Uses include removing hair from animal hides and softening with the juice extracted from the leaves in preparation for tanning (Van Wyk and Gericke,

[2]A mode of photosynthesis that utilizes water efficiently and enables the imbibition of carbon dioxide at night (Winter and Holtum, 2007)

2017). The root of other species in the ice plant family are used for beer brewing (Watt and Breyer-Brandwijk, 1932; Fox and Norwood Young, 1982; Van Wyk and Gericke, 2017).

Soutslaai is a stress-tolerant halophyte during its adult stages (El-gawad and Shehata, 2014). Stresses on *soutslaai* lead to quicker maturation with flowering and seed formation occurring as physiological, molecular and biochemical changes take place (Adams *et al.*, 1998). Under salt stress, the bladder cells of the adult plant become water reserves and sodium-storage organs (Adams *et al.*, 1998; He *et al.*, 2017). This is one adaptation to its aptitude for tolerating saline soils. The ability of *soutslaai* and dune spinach to withstand saline soils and accumulate salt in the top soil through senescence render it the ideal plant for soil restoration and generous yield under marginal conditions (Agarie *et al.*, 2007; El-gawad and Shehata, 2014). Another

Figure 2.7: Rainfed wild *soutslaai* on Dassen Island, Western Cape. © Amy Rusch

Figure 2.8: Bladder cells on *soutslaai* juvenile leaves. © Amy Rusch

Figure 2.9: *Soutslaai* fruit and flower.

Figure 2.10: *Soutslaai* seeds and capsules

adaptation strategy *soutslaai's* adopts to stresses like high temperatures, salinity, and drought conditions, is it's utilization of the CAM process (Adams *et al.*, 1998; Bartels *et al.*, 2005; Winter and Holtum, 2007; Atia *et al.*, 2014; He *et al.*, 2017). *Soutslaai* is a facultative halophyte that can switch its photosynthetic pathway from C_3 to CAM in order to handle abiotic stresses (Winter and Holtum, 2014). This mechanism provides the opportunity to utilise and assimilate more atmospheric carbon dioxide which is a growing concern with regards to climate change. The cultivation of edible plants, with such mechanisms, in semi-arid conditions can help reduce atmospheric carbon while providing a good source of food and nutrition security (Glenn *et al.*, 1999; Herppich and Schreiner, 2008; Cassaniti and Romano, 2011).

2.3.3 Palatability and Nutrition

The leaves and soft stems of dune spinach have a salty taste and can be used like spinach, eaten raw in grain salads, or cooked with other vegetables as demonstrated in Figures 2.11 and 2.12 (Van der Merwe and De Villiers, 2014). Dune spinach can also be fermented, pickled and used in stews and soups and particularly tasty in a stir fry (Rusch, 2016). Dune spinach pairs well with mushrooms, sun-dried or reduced tomato, grain salads and butter beans (Rusch, 2016). When boiled, dune spinach has a granular texture and tastes bland but mixed with Oxalis pes-caprae (sorrel/suring) and butter, makes tasty dish (Van Wyk and Gericke, 2017). The juicy leaves and stems of *soutslaai* are slightly salty and can be used raw or cooked as well as depicted in Figures 2.13 and 2.14 (Van der Merwe and De Villiers, 2014; Black, 2015; Mckeown, 2017). The plant parts can be juiced, used in salsas, and eaten as a green healthy alternative to bread (Rusch, 2016). Malnutrition and hunger are major concerns in South Africa particularly amongst economically resource-poor communities whose largest victims are children (Faber and Wenhold, 2009; Laurie *et al.*, 2017).

While there is scarce information on the nutritional composition of dune spinach (*T. decumbens*), its relative called *Tetragonia expansa* (New Zealand spinach) is also native to New Zealand, Australia, Argentina and Japan and currently commercially cultivated in Australia (Cecilio Filho *et al.*, 2017). A summarised tabulation, adapted from listed references, comparing selected nutritional quantities of indigenous and conventional vegetables is given in Table 2.1. In the past, New Zealand spinach had been observed on the KwaZulu-Natal beaches and the Transvaal (Fox and Norwood Young, 1982). Amino acids in human nutrition are necessary precursors for protein synthesis. A study by Słupski *et al.* (2010) showed that while raw New Zealand spinach was found to have good nutritional value with total amino acid even higher after cooking and freezing, it contained only 64 % and 41 % of amino acids present in spinach and kale respectively (Jaworska and Kmiecik, 1999). For this reason, New Zealand spinach was recommended as suitable for processing as a frozen product and a convenience food. The same can be said for dune spinach. Additionally, New Zealand spinach was reported to be high in vitamin C though not higher than broccoli, kale and cauliflower (Wheeler *et al.*, 1939). In another study, Jaworska and Kmiecik (1999) compared the accumulation of selected mineral elements between New Zealand spinach and spinach (*Spinacia oleracea L.*). It was observed that while New Zealand spinach had good mineral levels, spinach was higher at fresh weight. Based on this result it was concluded that New Zealand spinach is an alternative good source of calcium, magnesium and iron Jaworska and Kmiecik (1999). Regarding *soutslaai*, El-Darier (1992) reported that the annual mean content of *soutslaai* leaves and stems was highest for sodium and calcium and (Miszalski *et al.*, 1998) reported *soutslaai* antioxidant activity with the aid of iron, manganese,

Figure 2.11: Oep ve Koep's Sandveld dumplings Viljoen (2012)

Figure 2.12: Dune spinach and pickled veldkool (Rusch, 2016)

Figure 2.13: *Soutslaai* stems (Vered, 2016)

Figure 2.14: Young shoots of *soutslaai* (Vered, 2016)

copper and zinc. Antioxidant and antibacterial properties have been found in *M. crystallinum* (*soutslaai*) and *Carpobrotus edulis*, another member of the ice plant family and indigenous to the Fynbos Biome (Miszalski *et al.*, 1998; Agarie *et al.*, 2009; Bouftira *et al.*, 2012). *C. edulis* is more commonly known as sour fig, *ghaukum* in Khoi, *ikhambi lamalawu* in Zulu[3] and *suurvy* in Afrikaans (Van Wyk and Gericke, 2017). While in Bouftira *et al.* (2012) sour fig had a higher antioxidant activity than *soutslaai*, in Agarie *et al.* (2009) *soutslaai* had double the antioxidant activity of lettuce. The antioxidant activity in *soutslaai* and sour fig was due to the presence of flavonoids and polyphenols. As a result of their antioxidant and antibacterial properties, sour fig and *soutslaai* have been used as traditional treatments of fungal and bacterial infections, dysentry, lung inflammation, and as a remedy for kidney and liver problems (Watt and

[3] *moriana-wa-ditsebe* in Sotho

Table 2.1: Comparing nutrition of indigenous vegetables

Nutritional Quality	Spinach	Kale	Lettuce	New Zealand Spinach	*SoutSlaai*	Amaranthus hybridus
Potassium (g/kg)	6.46	20.7	3.7513	3.78	22.28*	7.7
Phosphorus (g/kg)	0.47	4.6	NF	0.24	NF	6.04
Calcium (g/kg)	2.25	32.4	0.3913	1.07	45.85*	3.39
Magnesium (g/kg)	0.73	2.08	0.216	0.45	1.8*	1.65
Sodium (g/kg)	0.27	9.73	0.08	0.87	42.98*	4.27
Iron (g/kg)	0.046	0.113	NF	0.042	NF	0.0205
Dry matter (g/kg)	91.3	180.8	0.1	61.9	NF	191.6*
Vitamin C (g/kg)	0.75	1.12	0.18	0.44	NF	0.86
Protein (g/kg)	48.8	7.6	9.15 (soluble)	49.8	NF	60
Total amino acids	23.61	36.21	6.42*	15.01	NF	886
Aspartic Acid (g/kg)	2.49	3.49	0.44*	1.65	50	12.2 (grain)
Glutamic Acid (g/kg)	2.84	4.5	0.78*	2.08	76	25.1 (grain)
Proline (g/kg)	1.43	4.34	0.35*	0.94	4.5 (mmol/kg)	47.2*
Nitrate NO3 (g/kg)	14.68*	15.63*	0.6	0.0284	2.3	5.31*
Nitrite NO2 (g/kg)	none	0.86*	NF	0.0065	0.03	NF
Oxalates (g/kg)	128.72*	23.02*	NF	0.119	2.3	38.58*
Flavanoids (¯g/mg)	1	6.46	7.59*	NF	0.0048	0.54
Phenols (¯g/mg)	NF	0.38	63.95*	58.2	0.0239	2.51
Antioxidative activity	NF	Present	NF	Present	Present	Present
Antibacterial activity	NF	NF	NF	Present	Present	Present

* indicates g/kg by dry weight; NF indicates value not found

References: (Uusiku *et al.*, 2010; Palombini *et al.*, 2013; Odhav *et al.*, 2007; Andini *et al.*, 2013; Mziray *et al.*, 2001; Schieber *et al.*, 2004; Olsen *et al.*, 2009; Zhang *et al.*, 2018; Jaworska and Kmiecik, 1999; Rosa and Heaney, 1996; Villiers *et al.*, 1995; Wheeler *et al.*, 1939; Gil *et al.*, 1999; El-Darier, 1992; Bouftira *et al.*, 2012; Korus and Lisiewska, 2011; Erdogan and Onar, 2011; Rose *et al.*, 2011; Koudela and Petříková, 2008; Jaworska, 2005; Słupski *et al.*, 2010; Lisiewska *et al.*, 2011; Hattori *et al.*, 2013; Lisiewska *et al.*, 2008; Yen *et al.*, 1995; Amaro *et al.*, 2011)

Breyer-Brandwijk, 1932; Bouftira *et al.*, 2012). Consequently, they can also be used as cosmetics (Bouftira *et al.*, 2008).

Notably, proline[4] and D-pinitol/D-ononitol[5] have been shown to increase in quantity for both drought and salt-stressed *soutslaai* plants with a maximum value of 58.5mg of pinotol per unit dry weight of *soutslaai* (Yen *et al.*, 1995; Shevyakova *et al.*, 2003; Agarie *et al.*, 2009). There is some antimicrobial activity in raw New Zealand spinach and also produces proline (94mg/100g edible portion) which increases after cooking (Słupski *et al.*, 2010; Neubauerová *et al.*, 2011). *Soutslaai* is also an excellent source of metabolites such as amino and organic acids, sugars and sugar alcohols which increase when the plant is exposed to salt conditions (Barkla and Vera-Estrella, 2015). As both *soutslaai* and dune spinach naturally occur in the coastal salty soils of the CFR, we can deduce that those growing in the wild under marginal conditions have good concentrations of minerals, metabolites, antioxidant and antibacterial properties. The carbohydrate

[4] A non-essential amino acid that aids in healing wounds, strengthening muscles and joints and collagen production

[5] A plant-based sugar-like molecule that acts as an anti-diabetic agent for type II diabetes (Bartels *et al.*, 2005; Agarie *et al.*, 2009)

nutritive value of at least six species indigenous to the Western Cape are documented by Singels *et al.* (2016). The nutritive value of other traditional leafy vegetables used in sub-Saharan Africa are listed in Wehmeyer (1986), Odhav *et al.* (2007) and Uusiku *et al.* (2010). They all contained high levels of nutrients providing up to 10 % of the recommended daily allowance for minerals (Aletor *et al.*, 2002; Bvenura, 2014; Mavengahama *et al.*, 2014; Satter *et al.*, 2016; Omondi *et al.*, 2017). Indigenous leafy vegetables are an excellent alternative source of food and nutrition with enormous health benefits.

2.4 Agronomic Potential of Cape Wild Foods (Fynbos Ecology)

2.4.1 Climatic Conditions

South Africa is a geologically and climatically vast and diverse country and its climate varies from Mediterranean to temperate to subtropical, and even desert. The Western Cape has a Mediterranean climate and receives winter rainfall. The fynbos biome's mean annual rainfall is about 480mm (Rebelo *et al.*, 2006). The longest daylight hours and highest temperatures are experienced from December to February (summer), with regional average summer temperatures ranging from 15 to 25 °C. Winter occurs from May to August, with average temperatures ranging from 7 °C to 15 °C (Van Rooyen and Janssen, 2010; Manning, 2013). Most plants flower during spring time which is from August to September and lie dormant during the dry summer months (Van Rooyen and Janssen, 2010). This presents an opportunity to utilize edible fynbos species as food sources within increasingly arid and dry conditions.

2.4.2 Soil Degradation, Erosion and Conservation

High mountains are a major feature in the landscape of the CFR. Not only are the mountains laced with beautiful fynbos vegetation and flora, but they also serve as water catchment areas. The broad variation in soil types and rainfall quantities across the province are major factors determining vegetative types and their distribution in the Western Cape (Van Rooyen and Janssen, 2010). There are 73 soil forms that have been classified into 14 soil groups based on specific materials and the horizons in which they occur in South Africa. These groups are organic, humic, vertic, melanic, silicic, calcic, duplex, podzolic, plinthic, oxidic, gleyic, cumulic, lithic and anthropic. Twelve of the fourteen groups of soil can be found on the Western Cape, with the most dominant soil groups being the silicic, calcic, podzolic, plinthic, gleyic, duplex, oxidic, cumulic, and lithic (Fey, 2010).

A high diversity of fynbos species can be found around the Cape mountain area that has plinthic and cumulic soils (Table Mountain Sandstone), quartzite (Witteberg Quartzite), and lithic soils of Caledon (Bokkeveld shale group) (Goldblatt, 1997; Fey, 2010; Coetsee *et al.*, 2015). In the lowlands, the sandstone, quartzite, and shale soils have been eroded exposing granite and old Malmesbury shales that present as rock substrates (Fey, 2010; Esler *et al.*, 2015). It is on the nutrient deficient and acidic sandstone and quartzite substrates that fynbos will typically be found growing (Fey, 2010; Manning, 2013). Fynbos is also found along the coastal sand and limestone substrates (Van Rooyen and Janssen, 2010).

Most of the soils described as occurring in the Western Cape have top soils that are highly bleached, leached, lacking in soil nutrients, acidic, saline or sodic. This would classify them as generally poor soils (Mills and Fey, 2004; Rebelo *et al.*, 2006). Yet, fynbos vegetation occurs along almost all these soil profiles. In order to grow most commercial crops, there is need for mitigations such as liming, gypsum application for sodicity and salinity, irrigation, artificial drainage, tillage practices, and many other strategies just to get the soil ready and suitable for the preferred crop (Katan, 2000; The Montpellier Panel, 2013; Crusciol *et al.*, 2016; Parwada and Van Tol, 2016). Indigenous edible species that are locally adapted to these soils do not require extensive application of energy and resources (Hasanuzzaman *et al.*, 2014). Instead, individuals, farmers, communities can work with nature to utilize these edible species in the context of their natural environment.

Soil is an important resource in agroecology that must be conserved and replenished. Good soil management is one of the pillars of sustainable agroecological practices. Soil conservation involves the enhancing and maintaining of soil health or quality for the benefit of what grows on it and what lives in it (Hathaway, 2016). Threats to soil quality have ranged from environmental to social to economic motivations (Archer *et al.*, 2008). These threats include industrialisation, urbanization, over-fertilization, soil surface crusting, soil erosion, leaching, over-grazing, deforestation and many more (Walton, 2006; Cassaniti and Romano, 2011; Parwada and Van Tol, 2016). Soil quality is too complex a concept to be defined by one component or factor and must always be approached holistically. Soils of high quality are those whose physical, nutritionally, biological and chemical qualities are ideal for soil fauna and plants to thrive (Katan, 2000). Some of these qualities include texture, soil organic matter, have good nutrient availability, infiltration rate, good water holding capacity, rich with microbial biodiversity, soil organic matter, amongst others (Ladd *et al.*, 1994). Some research has been done on the effect of fynbos species on soil quality (Walton, 2006; Abanda *et al.*, 2011; Cassaniti and Romano, 2011; Coetsee *et al.*, 2015). What has been established is the potential to use some salt tolerant fynbos species to restore saline soils (Balakrishnan, 2007; Abanda *et al.*, 2011; Cassaniti and Romano, 2011).

2.4.3 Precipitation and Drought

The Fynbos Biome receives between 400 to 2000 mm of rainfall a year in general during the winter (Helme and Schaminee, 2012). The mountain areas receive more rainfall (over 1000 mm/year) than the interior low lying regions (less than 250 mm/year) (Manning, 2013). Interestingly, rainfall becomes non-seasonal towards the east of the CFR as the climate transitions to subtropical summer rainfall (Walton, 2006). In summer, cloud forming moisture is brought in by South-Easterly winds. Up to 500 mm of precipitation is added to the CFR through these clouds during the summer (Walton, 2006; Helme and Schaminee, 2012; Manning, 2013). Vegetation type is affected not only by soil type but rainfall quantities as well making it well suited for a wide range of agricultural produce.

Drought is a major limiting factor to agricultural production particularly for agrarian communities in the drier parts of the developing world. FAO (2014) defines drought as an extended period of deficient precipitation compared to the statistical multi-year average for a region, resulting in water shortages for some activity, group, or environmental sector. Chronic dry conditions and sporadic rains are disastrous for farmers that completely dependent on the rain. According to Malagnoux (2007), around 30 % of land globally is classified as arid or semi-arid. Farmer's Weekly (2015) reported that rainfall data from the Agricultural Research Council (ARC) showed that precipitation deficits in the Western Cape production area lead to dry conditions towards the end of the winter rainfall season in 2015. Figure 2.15 shows the annual mean rainfall in the Western Cape for 2018 where up until September 2017, only 30 % of rainfall, compared to the long-term average, had received (Walther *et al.*, 2002; Roux, 2014). With the previous lowest SPI having been recorded in 1980, the current drought conditions have led to catastrophic job losses for seasonal farm workers, one of the groups most vulnerable to poverty in the Western Cape (Farmer's Weekly, 2015; Erasmus, 2017; SSA, 2017). The low levels of storage water have led to a reduction in cash crop production especially through summer irrigation. Decreased food production has led to loss of livelihoods for vulnerable communities, increased food prices and consequently, food insecurity.

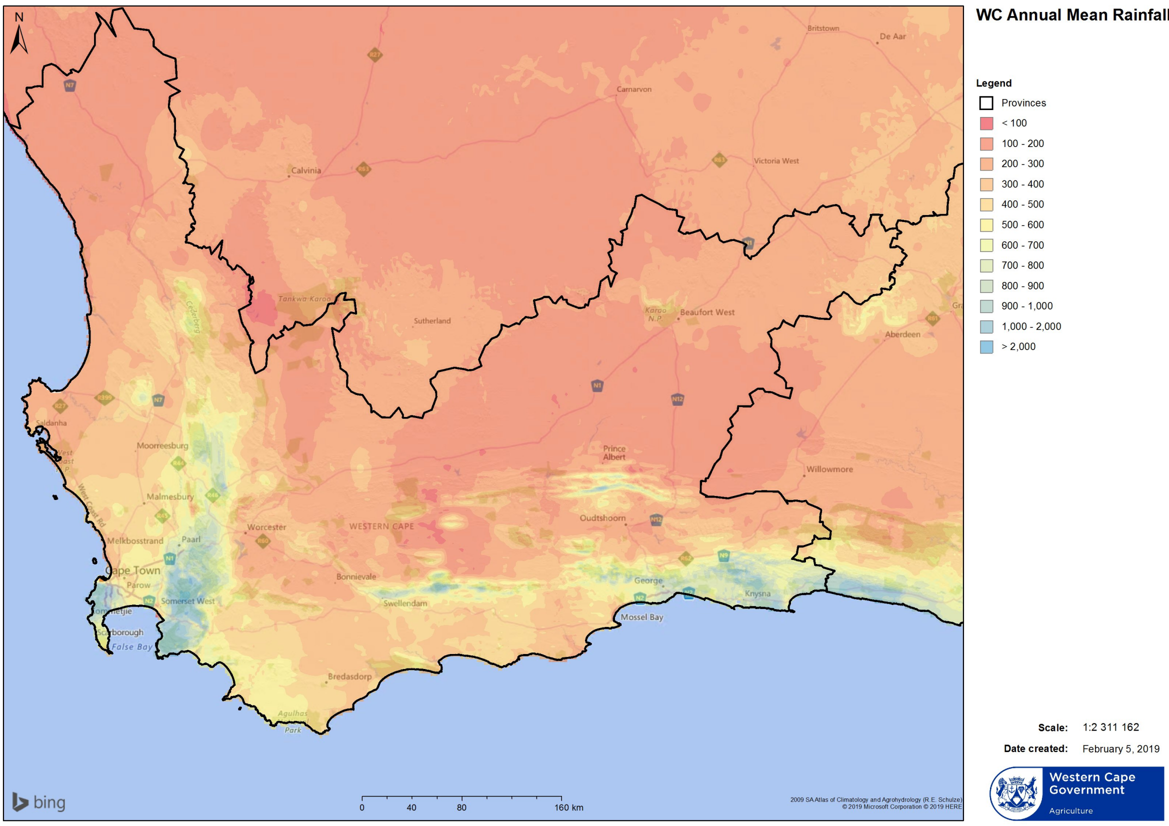

Figure 2.15: **Annual mean standardised precipitation index for Western Cape as at 5 February 2019 (Cape Farm Mapper, 2019)**

2.4.4 Potential Use of *Tetragonia decumbens* and *Mesembryanthemum crystallinum* as Vegetable Crops

According to Herppich and Schreiner (2008), there is limited commercial use of *soutslaai* though its is cultivated in New Zealand, Australia, India and California as a rare leafy vegetable. In South Africa, there is no commercial use or cultivation of this edible plant as a leafy vegetable even though it is indigenous to the Western Cape of South Africa. The halophytic nature of both species enables them to survive the dry, hot summer months and tolerate saline soils (Adams *et al.*, 1998; Orach *et al.*, 2000; Bartels *et al.*, 2005; Agarie *et al.*, 2007; Yousif *et al.*, 2010; Chiang *et al.*, 2016). For instance, Rusch (2016) observed that *soutslaai* successfully seeded while dune spinach was reported to have re-sprouted during the prevailing drought that was being experienced in the Western Cape. Hence, possibility for repeated harvesting without the need to save seed and re-sow every year hsa potential to reduce seeds costs (Rusch, 2016). Notably, both species are highly prolific with potential to amass biomass weighing between 50g up to 20kg (Glenn *et al.*, 1999; Abbott *et al.*, 2000; Bohnert and Cushman, 2000; Agarie *et al.*, 2009; Yousif *et al.*, 2010; Cassaniti and Romano, 2011; El-gawad and Shehata, 2014; Riccardi *et al.*, 2014; Wendelberger and Richards, 2017). Additionally, low-salt irrigation treatment of soutslaai can increase yield and has no negative effect on taste (Herppich and Schreiner, 2008). *Soutslaai* and other halophytes can take up elements prone to toxicity such as cadmium and chlorine and can be used to remediate and utilize marginal soils and water (Watkins *et al.*, 1988; Villiers *et al.*, 1995; Ghnaya *et al.*, 2005; Balakrishnan, 2007; Jordan *et al.*, 2009). Both species have antioxidant and antimicrobial activity which has been reported to be one of the reasons soutslaai never has a pest, disease and fungal infestation (Bohnert and Cushman, 2000; Bouftira *et al.*, 2008, 2012). As a consequence, both have health and beneficial properties (Yen *et al.*, 1995; Agarie *et al.*, 2009; Hattori *et al.*, 2013; Barkla and Vera-Estrella, 2015).

In nature, *soutslaai* also tolerates low temperatures and accumulates salt on the top soils which tends to exclude other species from growing (Adams *et al.*, 1998; Wendelberger and Richards, 2017). Seeds of both species also survive hot dry summers and for that reason, spontaneous germination can be observed even after brief bouts of rain (Bohnert *et al.*, 1995; Goldblatt, 1997; Adams *et al.*, 1998; El-gawad and Shehata, 2014; Rusch, 2016). Germination of *soutslaai* seed is reported to be erratic and dependent on its position in the capsule and season (Adams *et al.*, 1998). However, light surface sowing on many growth mediums (agar, vermicullite and light soils), an average temperature of 21 °C and slighty salty conditions are the reported ideal germination requirements (Adams *et al.*, 1998; Chiang *et al.*, 2016). *Soutslaai's* seeds can take from one to over thirty days to germinate (Adams *et al.*, 1998). However, seed dormancy is completely broken with exposure to dry heat treatment (Visscher *et al.*, 2018). Furthermore, due to *soutslaai's* antibacterial properties, it naturally has potential to resist insects, viral, bacterial and fungal infections (Bohnert and Cushman, 2000).

While there is limited research on dune spinach, New Zealand spinach is an excellent analogue for dune spinach which has been referred to by Van Wyk (2011) as being a potential value as a new food for commercialization. The valuable adaptive nature of *soutslaai* and dune spinach to withstand biotic and abiotic stresses make them ideal plants to propagate. Wild vegetables have great agronomic potential in regions experiencing the adverse effects of drought, high temperatures and soil salinity and sodicity. Naturally, attention needs to be given to the cultivation and use of wild indigenous vegetables in order to enhance local food systems. Cultivation of seasonal wild vegetables in urban gardens, by small scale farmers can eventually upscale to commercial markets could promote increased food and nutrition security for all. Lastly, there is also great potential for export to a niche international market looking for *soutslaai* seed and fruit.

2.5 Consumer Perceptions and Acceptance of Indigenous Vegetables

2.5.1 Context

Previous hunter-gatherer societies of the CFR, in the Middle to Late Stone Age, traditionally foraged and utilized many plant species, especially those with underground storage organs (Singels *et al.*, 2016). Various storage organs and edible leafy plant species were used by first nation peoples as sources of carbohydrates and other nutrients, while marine life and game provided protein (Marean, 2010; Kyriacou *et al.*, 2014; De Vynck *et al.*, 2016*b*,*a*; Singels *et al.*, 2016). It is reported that these hunter-gatherer communities were not historically agrarian and so edible plant species that served as a source of nourishment for these early societies where not previously cultivated (Wehmeyer *et al.*, 1969; Schrire, 1980; Testart, 1988; Viljoen, 2006; Pirie, 2011; Layton and Rowley-Conwy, 2013). Colonization, removal of indigenous people from cultural lands, and apartheid, subsequently led to a Western Cape society that is completely disassociated from the land and knowledge of the useful plants it offers (Van Rooyen and Janssen, 2010; Kuhnlein *et al.*, 2013; Cavanagh, 2013). The introduction of cereal crops by European colonisers in the 1700's followed by the erosion of the knowledge systems around edible plant species has left only small marginalised communities of first nation descendants as a testament to the earlier hunter-gatherer societies that existed before (Viljoen, 2006; Cavanagh, 2013; La Croix, 2018). In consequence, it is among the elderly members of these small communities that knowledge of the useful plants is held (De Vynck *et al.*, 2016*b*; Singels *et al.*, 2016). Nonetheless, over the last 300 years, a total of 1002 indigenous edible plant species have been documented (Van Wyk and Gericke, 2017; Manning, 2013; De Vynck *et al.*, 2016*a*).

2.5.2 Rediscovering Indigenous Foods in the Western Cape

The history of colonisation and apartheid in South Africa is a major reason for the lack of knowledge on the indigenous foods of the Western Cape. Fortunately, the importance of forgotten native plants in providing a source abundant biodiversity and environmental hardiness has been recognised and strides have been made to document indigenous foods around the Western Cape. Furthermore, indigenous knowledge on edible plants can be generated as local people interact with their landscapes (Stone, 2016; Grangeon, 2018). Local indigenous information on observations and experimentation of local plant species growth patterns, behaviour and uses is useful in contributing to nutrition and food security, even if the local people may not always be indigenous to the landscape (Rusch, 2016; Lindow, 2017). Consequently, community participation and knowledge sharing is an important consideration when it comes to indigenous knowledge generation and application to local food systems (Vorster, 2007).

Documentation of indigenous knowledge around indigenous foods generated through collaboration and community participation can lead to sustainable environmental conservation, social wellbeing, food sovereignty and nutrition security. A thriving network of food activists and innovators exists to rediscover and revive local knowledge around edible indigenous wild plants in the Western Cape. Some include wild food innovators such as Chuma Mgcoyi, Nazeer Sonday, Zayaan Khan, Loubie Rusch and Kobus van der Merwe (Even-Zahav, 2016; Lindow, 2017). Initiatives and gardens exist that engage communities particularly young people in growing and learning about Cape wild foods (Rusch, 2016; De Bruin, 2018). Some gardens and initiatives include the *Moya we Kaya* Garden in *Khayelitsha*, *Ikhaya* Food Garden at *Isikhokele* Primary School in *Khayelitsha*, the indigenous food garden at the Sustainability Institute, the Philippi Horticultural Area Food and Farming Campaign, the Slow Food Foundation and *Tyisa Nabanye* permaculture farm.

Cape wild foods have culinary value (Schumann, 2015; Lindow, 2017; Van der Merwe and De Villiers, 2014; Vered, 2016; Grangeon, 2018). Both dune spinach and *soutslaai* are being served in restaurants such as Wolfgat and *Oep ve Koep* in Paternoster (Figures 2.13 and 2.14), West Coast and Table Bay Hotel in Cape Town, respectively. In Stellenbosch, Jardine restaurant serves dune spinach and other wild foraged foods and Chef Kobus van der Merwe has published a book called *Strandveldfood* that includes recipes on *soutslaai* and dune spinach (Van der Merwe and De Villiers, 2014). Renata Coetzee, nutritionist by training, author of over four books on the traditional food cultures of South Africa, mentioned dune spinach and *soutslaai* in her two books Kukumakranka and A Feast from Nature (Coetzee, 2010, 2015).
As interest grows in these edible fynbos species and the consumer base expands, it becomes more important to preserve and protect any indigenous knowledge available on these wild foods and ensure that local and especially economically resource-poor communities are not exploited (Reinten and Coetzee, 2002; Lindow, 2017; Grangeon, 2018). Additionally, generating agronomic and technical knowledge on wild food cultivation is an early step in preparing local farmers for potential consumer demand (Chivenge *et al.*, 2015; Cecilio Filho *et al.*, 2017). This could potentially create a sustainable source of income that could help improve livelihoods for resource poor communities and small-scale farmers (Akhtar *et al.*, 2016). While scientific information on wild edible plants of the Western Cape may be limited, the success of more sustainable and regenerative interventions to ensuring food security must take into account all the complex systems involved.

2.5.3 Preference and Perception

Consumers have different values and food preferences that can be based on a multitude of factors. These include sensory appeal, availability, culture, personal tastes, perceptions, information availability, education, and religion, amongst other factors (Heinrichs and Ellison, 2016; Appleton *et al.*, 2017). Numerous studies have to be carried out to investigate consumer preferences and tastes and how it affects food choice and attitudes (Wright *et al.*, 2001; Wilcock *et al.*, 2004; Scholtz and Bosman, 2005; Badham, 2008; Marreiros and Ness, 2009; Barrett *et al.*, 2010; Burnett *et al.*, 2011; Hansen, 2012; Hough and Sosa, 2015; Heinrichs and Ellison, 2016; Appleton *et al.*, 2017; Faber *et al.*, 2017). According to Heinrichs and Ellison (2016), the relationship between the knowledge and vegetables consumption has warranted the push toward much academic research on how to increase vegetables intake through the provision of information. Unfortunately, there are fewer studies being conducted on how to increase indigenous vegetables intake by consumers and the barriers surrounding consumption (Vorster, 2007; Dahlia *et al.*, 2012; Matenge *et al.*, 2012; Senyolo *et al.*, 2014; Bvenura and Afolayan, 2015; Penafiel *et al.*, 2016).

Consumer preferences are subjective individual tastes measured by how satisfied the consumer will be with the consumption of a set of goods. In addition, the likes and dislikes of the consumer are not determined by the ability to purchases preferred products. However, it is notable that vegetable consumption is generally low in South Africa, particularly indigenous vegetables (Jansen van Rensburg *et al.*, 2007; NICUS, 2007; Vorster, 2007; Badham, 2008; Dweba and Mearns, 2011; Bvenura and Afolayan, 2015; Faber *et al.*, 2017; Appleton *et al.*, 2017). Consumers preferences may also be determined by how concerned they are with the production process of the foods they consume. Environmentally conscious consumers are more inclined to support local producers and markets (Burnett *et al.*, 2011). A study showed that consumers preferred fresh vegetables to frozen ones, even when additional information on the nutrition of frozen vegetables was provided (Heinrichs and Ellison, 2016). The media would help promote the consumption of indigenous food to young urban dwellers who have been cut off from the chain of information and knowledge regarding these vegetables. With the goal of most young people to live healthy lives, it is most likely that media publicity would reach them with specific information about the environmental and health benefits of consuming indigenous vegetables. Local farmers and first nation people would also benefit from the cultivation and production of these indigenous vegetables.

2.5.4 Adoption

Adoption of these wild vegetables depends on taste preferences, availability, ease of preparation as well as indigenous knowledge around the vegetables (Vorster, 2007; Appleton *et al.*, 2017). Hence, community participation in academic research is vital to promoting the adoption of indigenous vegetables (Martin *et al.*, 2010; Hoeven *et al.*, 2013; Laurie *et al.*, 2017). Sensory attributes have always been an important factor in determining attitudes towards food. For vegetables in particular, colour, smell, appearance and taste play a big role in vegetable choice and consequent adoption (Wright *et al.*, 2001; Barrett *et al.*, 2010; Hoeven *et al.*, 2013; Senyolo *et al.*, 2014). According to a review by Heinrichs and Ellison (2016), literature has shown that consumers in America are more inclined to choose food based on taste preferences and that taste preferences outweigh nutritional value and price. Moreover, knowledge can affect vegetable consumption as nutritional information usually translates into increases in consumption of adequate amounts of vegetables (Heinrichs and Ellison, 2016; Gido *et al.*, 2017). Indigenous foods are believed to be highly nutritious, less processed and have health benefits (Burnett *et al.*, 2011; Hoeven *et al.*, 2013). Generally, it is the older generations of communities that have adopted and utilise indigenous vegetables (Heywood, 2011; Matenge *et al.*, 2012; Bvenura and Afolayan, 2014; Lindow, 2017).

According to Bvenura and Afolayan (2015), 103 species from 33 families of wild vegetables have been reported to be in use in five of the nine provinces of South Africa. Of these five provinces, the Limpopo Province reported the highest number of indigenous vegetable species in use, followed by KwaZulu Natal and North West, Eastern Cape, with the lowest number of use reported in Mpumalanga. Unfortunately, much of the indigenous knowledge around native vegetables has not been passed down to the younger generations who have generally migrated to the urban and peri-urban communities (Bvenura, 2014). Some of the barriers to adoption and consumption of wild vegetables includes the lack of interest in learning about them, fear of poisoning due to inability to distinguish edible species, wariness or dislike of the taste (Vorster, 2007; Mavengahama *et al.*, 2013; Bvenura and Afolayan, 2015). Furthermore, the progressive westernisation of African culture, tastes, and subsequently diets, has not aided the adoption or increased consumption of wild vegetables. Indigenous vegetables in the Western Cape have specific tastes, usually salty, sour or bitter, which will be an acquired taste for some people (Black, 2015; Stone, 2016; Rusch, 2016).

The adoption and cultivation of indigenous foods presents an opportunity to improve local food systems. Abundance of these vegetables growing in the wild under marginal conditions demonstrates the ease of production and input it would take to cultivate and produce these species. Consumption of indigenous vegetables diversifies diets while providing sustainable sources of food and nutrients. Consequently, there comes an overall effect of enhancing local economies while improving the health of, particularly, economically resource-poor local consumers (Burnett *et al.*, 2011). Therefore, availability and affordability become important attributes for consumer adoption, especially if the taste is acceptable. A consistent supply of the fresh and good quality indigenous vegetables is ideal in the consumerist culture that currently exists (Dahlia *et al.*, 2012). While this might be ideal, a question that must be asked is whether the consistent supply of high-quality fresh produce in every season is always necessary. The adoption of a more sustainable way of producing local food may entail that supply is seasonal because the source is seasonal. Additionally, a shift in thinking that acknowledges that the quality of sustainably produced indigenous food may not always be aesthetically perfect due to the benefit sharing regenerative systems such as agroecology promote with nature. For instance, minimised use of chemicals to control pests may mean needing to share some of the produce with beneficial insects that control pests (National Research Council, 2010; Burnett *et al.*, 2011). In light of increasingly scarce resources and food and nutrition insecurity, the responsible production and consumption of food is imperative.

2.6 Conclusion

Indigenous vegetables utilization is one of the many links between responsible production and consumption. Increasingly hot, dry and saline conditions influenced by climate change and the effects of industrial agriculture give way to the utilization of edible species that can tolerate such conditions. Halophytes in particular, not only utilize water efficiently but can produce large quantities of biomass under marginal irrigation and soils. Consequently, they can be used to reclaim marginalised soils for agronomic use. They provide an alternative source of nutritious food and many health and medicinal benefits by those possessing antioxidant and antimicrobial qualities. The biodiversity of indigenous plants must be cherished and a good foundation has been laid by the documentation of many species and their ecology. However, there is still much knowledge to be revived and rediscovered. More research is needed on wild edible and other useful plants. Lastly, exploring potential consumers perceptions about indigenous foods from the Western Cape can provide information that may be helpful for growers willing to adopt these species. Efforts to securing food and nutrition security in the face of challenges such as climate change and faster consumption of scarce resources compared to their replenishment, should be motivated by human-centred solutions. However, this utilitarianism must go hand in hand with the responsibility that comes with restoring, conserving, preserving and reviving the resources being utilised. While agricultural innovations seeking to feed the world have led to much pollution and depletion, further disconnecting the importance of people and their relationship to the environment would be a mistake. Thus, research that is tailored to generate scientific information that takes into account and acknowledges local knowledge and experience, gives a more holistic way of advancing society.

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Chapter 3

Agronomic Performance of *Tetragonia decumbens* and *Mesembryanthemum crystallinum*

Abstract

Cape wild vegetables can useful tools in linking biodiversity and agriculture in a way that increases environmental, economic, socio-cultural, and nutritional sustainability. The aim of this study was to determine the agronomic performance of *Tetragonia decumbens* (dune spinach) and *Mesembryanthemum crystallinum* (*soutslaai*). This two-part study investigated the effect of water and soil regimes on biomass accumulation, growth and physiological responses of the two Cape wild vegetables. A tunnel experiment was conducted at the Welgevallen Experimental Farm (WEF), Stellenbosch University. A completely randomised design was applied with three treatments and a control for the water regime trial and two treatments and a control for the soil regime trial. The water regime trial treatments were: no watering as control and 25 %, 50 %, and 80 % pot water holding capacity as test treatments. The soil regime trial had dune sand (control) from Kommetjie, Western Cape and sandy soil from the Sustainability Institute soil (SI) and loamy soil from the Welgevallen Experimental Farm (WEF) as test treatments. Though the water treatments had no significant effect on the agronomic performance of dune spinach and *soutslaai*, we conclude that the 25 % and 50 % water treatment levels are sufficient for growth of dune spinach and *soutslaai* when grown in the soil in which they naturally occur. Results from the soil regime trial indicated that there were significant increases in agronomic performance of dune spinach and *soutslaai* among soil treatments except for number of dune spinach runners and *soutslaai* leaf pairs. It was concluded that agronomic performance is maintained under water scarce conditions. Additionally, it can be improved significantly when dune spinach and *soutslaai* are planted in more fertile sandy soils and well aerated loamy soils.

Keywords: dune spinach, *soutslaai*, Cape wild vegetables, agronomic performance

3.1 Introduction

Rediscovering local knowledge and resources such as indigenous foods that are well adapted to their local environments is a vital mitigation strategy against various environmental challenges. Reviving the use of indigenous leafy vegetables at household level as alternative or additional food and nutrition sources can contribute to food security (Vivus, 2016; Even-Zahav, 2016). In addition, if integrated into cropping systems, these vegetables' agrobiodiversity potential can have a direct impact on agroecological challenges such as poor soil quality, salinity, erosion, increasing pests and diseases, drought, and sporadic rainfall, amongst others (Van Wyk, 2011; Mavengahama, 2013). Furthermore, indigenous vegetables classified as halophytes and/or plants that use the four carbon molecule (C_4) and Crassulacean acid metabolism (CAM) pathway can help mitigate climate change impacts such as drought, increasing temperatures, arid conditions and atmospheric carbon (Bohnert *et al.*, 1995; Tsiantis *et al.*, 1996; Ziervogel and Ericksen, 2010).

While many indigenous edible foods have received research attention in some provinces of South Africa, research of this nature has been scarce in the Western Cape (WC) of South Africa (Slabbert *et al.*, 2004; Hart, 2004; Jansen van Rensburg *et al.*, 2007; Vorster, 2007; DAFF, 2013; Mbatha, 2010; Dweba and Mearns, 2011; Matenge *et al.*, 2012; Mavengahama *et al.*, 2013; Bvenura, 2014; Mavengahama *et al.*, 2014; Bvenura and Afolayan, 2015; Omondi *et al.*, 2017; Agricultural Research Council, 2017; Du Plooy *et al.*, 2018). At least 1703 edible species have been identified in South Africa (Van Wyk and Gericke, 2017), and although over 103 of the species have been classified as wild vegetables, cultivation is mainly limited to five of the nine provinces of South Africa; viz Limpopo (58 %), KwaZulu Natal (27 %), Eastern Cape (22 %), North West (27 %) and Mpumalanga (3 %) (Bvenura and Afolayan, 2015). This may be due to a lack of systematic documentation of indigenous knowledge around plant use before indigenous communities were marginalised during the colonial and apartheid era (Warren, 1990; Soudien, 2011; De Vynck *et al.*, 2016*a*). Therefore, more recent studies have focused on documenting this indigenous knowledge to increase the body of information around beneficial indigenous plants, particularly in the WC (Manning, 2013; Kyriacou *et al.*, 2014; De Vynck *et al.*, 2016*a*,*b*; Singels *et al.*, 2016; Lindow, 2017; De Bruin, 2018).

Fynbos flourishes in infertile and often saline sandy soils and so edible plant species adapted to the poor soils and sporadic rainfall can be utilized (Lotter *et al.*, 2014; Mills and Fey, 2004; Roux, 2014; Chivenge *et al.*, 2015). In a study conducted in the Cape South Coast, 58 indigenous edible plants were identified out of a list of 140 edible, medicinal, and other useful plant species (De Vynck *et al.*, 2016*b*). Inspite of it biological and genetic diversity, the agronomic potential of the Fynbos Biome has been ignored in favour of its biological, aesthetic, health and medicinal values (Brooke and Crowe, 1982). In South Africa there is extensive interest and investment in fynbos for its medicinal and health benefits in tea products such as *rooibos* (*Aspalathus linearis*) and honey bush (*Cyclopia spp.*) (Reinten and Coetzee, 2002; Joubert and de Beer, 2011; Grangeon, 2018). Furthermore, much focus has been placed on developing the aesthetic and eco-tourism value of fynbos, with the fresh flower industry yielding over 5 million stems for export of Proteas alone in 2016/2017 (Le Maitre *et al.*, 1997; Conradie and Knoesen, 2010; Van Zyl and Goosen, 2017).

Increased interest coupled with limited information on the agronomy of indigenous vegetables in the WC presents an added threat onto their biodiversity and risk of genetic erosion if foraging continues without cultivation (Mavengahama *et al.*, 2013). Additionally, the established promotion of cash crop monocropping and urbanization continues to systematically eradicate these wild vegetables because they are considered as undesirable weeds, thereby increasing biodiversity loss (Thrupp, 2000; Kuhnlein *et al.*, 2013). Confounding socio-economic factors in the WC are the increasing unemployment rates, hunger and an ever-widening poverty gap (SSA, 2017). Therefore, the availability of technical production knowledge for use by rising young farmers can be a means to sustainably meet potential indigenous vegetable demand thereby potentially creating a source of income. Utilization of locally adapted edible species in environmentally friendly ways will promote responsible consumption and use of resources.

The focus of this chapter will be on two edible fynbos species, *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*). A detailed description of these two species has been given in Section 2.3. These halophytic plants naturally occur as salt-tolerant coastal plant communities (Adams *et al.*, 1998; Manning, 2013). For this reason, research on *soutslaai* in particular, has been focused on its plant growth, developmental stages, salt and drought tolerance mechanisms for genetic harvesting and phytoremediation potential (Bohnert *et al.*, 1995; Adams *et al.*, 1998; Cassaniti and Romano, 2011; Hasanuzzaman *et al.*, 2014; He *et al.*, 2017). Furthermore, the water use efficiency and carbon fixing capacity of *soutslaai* and dune spinach using CAM makes them the ideal climate conscious vegetables to adopt (Adams *et al.*, 1998; Ogburn and Edwards, 2010). The innate ability to transition into CAM allows these wild vegetables to use large quantities of carbon dioxide at night time which is then used for photosynthesis during daytime, thus increasing photosynthetic efficiency (He *et al.*, 2017). CAM, amongst other mechanisms, aids in the species' adaptation to drought and salt tolerant (Watkins *et al.*, 1988). These qualities are essential for sustainably growing food in ways that address the challenges of poor soils and scarce water conditions.

Both *T. decumbens* and *M. crystallinum* are in cultivation in various community gardens around the WC, but neither is formally commercialised or marketed (Black, 2015; Stone, 2016; Lindow, 2017; De Bruin, 2018). The aim of this paper was to determine the agronomic performance of *T. decumbens* and *M. crystallinum*. Specifically, the goal was to investigate the effect of water and soil regimes on biomass accumulation, growth and physiological responses of *T. decumbens* and *M. crystallinum*.

3.2 Methodology

3.2.1 Location of Study and Climatic Conditions

The location of both trials was in a tunnel at the Welgevallen Experimental Farm (WEF), Stellenbosch University, Western Cape, South Africa (33.9427 °S, 18.8664 °E). Overall, WC climate is Mediterranean with rainfall occurring during the winter months of April to September. Average rainfall in Stellenbosch over the last 10 years has been 463 mm (University of Stellenbosch, 2018). The maximum and minimum temperatures for the duration March to June (2018) at WEF are shown in Table 3.1. Figure 3.1 shows where the soil samples were collected from. The WEF, the SI in Lynedoch (33.9826 °S, 18.7687 °E), and Kommetjie, WC (34.137 79 °S, 18.322 621 3 °E).

Table 3.1: Maximum and minimum temperatures at WEF from March to July 2018

Month	March	April	May	June	July
Max Temp °C	30	31	29	28	28
Min Temp °C	20	19	17	11	12

Figure 3.1: Map of locations at which soil was collected and where the experiment was conducted. Image credit: Google Earth

3.2.2 Experimental Treatment and Design

The study was conducted as a two-part experiment consisting of a soil and water trial from April to July 2018. Both dune spinach and *soutslaai*, were subjected to the water and soil treatment trials. The experimental design used was a completely randomised design with 10 replications and a total of 196 plastic pots each with a volume of 3.4 dm^3 and mass of 1.5 kg of soil.

The water regime trial consisted of three treatment levels and a control (0 % (control), 25 %, 50 %, and 80 % pot capacity (PC)), while the soil trial had two treatment levels and a control (Kommetjie dune soil (control), SI soil, and WEF soil). Only the Kommetjie dune soil was used for the water regime trial as this is the soil in which both dune spinach and *soutslaai* naturally occur. Water holding capacity for both trials was measured by soaking pre-weighed samples of each type of soil. The soaked soils were then drained and weighed again, and pot capacity was measured by the difference between the two weights (Casaroli and de Jong van Lier, 2008). Total pot capacity was calculated at 80 % to avoid saturating all the pores.

All soil was collected at the depth of 0-30 cm. The control was passed through a 1 mm sieve due to considerable coastal debris and the other two soil types were passed through a 2 mm sieve. The control and SI soil were classified as sandy soils while the WEF soil was classified as being loamy. Soil analysis was carried out at Bemlab (Somerset West). Chemical characteristics of the soils are tabulated in Section 3.3.1. No additional nutrients or amendments were added to the soil. After harvest, replications of each treatment for both trials were mixed to obtain a representative sample for analysis. It was not the intention of this paper to investigate in detail the physical and chemical characteristics of the soil that was used for the study. However, general conclusions are drawn from an overview of the basic soil analysis that was carried out.

3.2.3 Plant Material and Agronomic Practices

Wild 6-month old seedlings of *T. decumbens* and seeds of *M. crystallinum* (*soutslaai*) were purchased from Cape Flats Life nursery[1]. There was no treatment done to the seeds or seedlings before planting and transplanting. Seedlings were transplanted into the pots, well-watered and allowed to acclimatise for three weeks because they were previously water stressed due to drought restrictions. *Soutslaai* seeds were manually separated from their capsules to facilitate easier germination. Since the seeds are very small, they were mixed with their capsules and same sand before conducting a very shallow planting. Seedlings were ready to be transplanted or thinned to one plant per pot after three weeks. Water treatments were introduced to the dune spinach plants four weeks after transplanting and two weeks after transplanting *soutslaai*, two weeks after transplanting. This was done because dune spinach was purchased as seedlings from a nursery under drought restrictions. The four weeks gave them enough time to recover from the water stress. *Soutslaai* was established enough for the treatments to begin four to five weeks after germination.

Plants were hand-watered three times a week according to the different assigned water treatments. This was based on the level of depletion in the 80 % water treatment level. Soils were aerated with a garden fork at least once every week. Plant height and size, leaf area index (LAI), stomatal conductance (SC), chlorophyll content index (CCI) were measured only on leaves that had at least 50 % mature green leaf area. Subsequent measurements were done every four weeks after transplanting and planting until harvest. Three leaves per replicate were used to collect the physiology parameters. Leaf area index was measured using the LI-3100C leaf area meter. Stomatal conductance was measured using a steady state leaf porometer on the abaxial leaf surface (Model SC-1, Decagon Devices, Inc, USA). The CCM-200 Plus chlorophyll content meter was used to measure the chlorophyll content index (Opti-Sciences, Inc, USA). Dune spinach height and *soutslaai* plant size was measured using measuring tape. For the purposes of this thesis, only final measurements were analysed for height, plant height and size, number of leaf pairs and runners, LAI, SC, and CCI.

Plants were weighed immediately after harvesting to avoid water loss. Biomass was calculated for all the plants in each treatment and dry matter content was obtained after oven drying the leaves at 65 °C for five days.

[1]A community organisation that encourages the planting and protection of indigenous flora. The dune spinach seedlings had been propagated from cuttings.

3.2.4 Statistical Analysis

All data was analysed using SPSS (Version 25) statistical package. One-way ANOVAs were ran to interpret the data. When the normality assumption was violated, the Kruskal Wallis test was ran and Welch's test was used when homogeneity of variance was violated (Hecke, 2013; Delacre *et al.*, 2017). Significant means were compared using either Tukey's post hoc or Games-Howell's multiple comparison tests at the 5 % confidence level. For the soil analysis, percentage error (fractional error $\times$ 100) was calculated to measure significant increases in soil nutrients measured before the trials and after. It must be noted that in this case, a percentage error of greater than 5 % was interpreted as significant increases while values lower than 5 % were interpreted as insignificant increases. Soil fertility before the trial was measured against South African soil standards compiled by Pieter Raath and Andrew Teubes, Appendix F.

3.3 Results

3.3.1 Soil Characterization

Tables 3.2 and 3.3 demonstrate the differences in soil characteristics before and after the soil and water regime trials. Based on the standards presented in Appendix F, analysis of the control (coastal sand) before the trial revealed acceptable levels of sodium, sulphur and boron. Additionally, it had a very high pH and excessive calcium content yet relatively low salinity levels and deficient in phosphorus, potassium, magnesium, nitrogen, copper, zinc and manganese. The SI sandy soil had an acceptable pH, phosphorus, sodium, sulphur, zinc, manganese and boron. However, it had a high salt concentration, excessive levels of calcium and magnesium and very low quantities of potassium, nitrogen and copper. Lastly, the WEF loamy soil was the least saline and had acceptable levels of pH, potassium, sodium , calcium, nitrogen, sulphur, zinc and manganese. However, it was deficient in magnesium, copper and boron. The SI and WEF soils had fair amounts of organic matter though still below the 5 % threshold. The control was deficient in organic matter content. Based on these values, it was deduced that the SI and WEF soils were more fertile than the coastal sand used as the control.

Only soil nutrient increases measured amongst the soils analysed after the trials are reported. Significant increases were only reported if the percentage error calculated between the parameters measured before and after the trial was greater than 5 %. That is to say, percentage errors greater than 5 % were interpreted as significant increases while values lower than 5 % were interpreted as insignificant increases.
Firstly, dune spinach increased OM (1.15 ± 0.24), carbon (0.67 ± 0.24), nitrogen (0.031 ± 2.88) and zinc (2.2 ± 0.29) in the Kommetjie soil while *soutslaai* increased only nitrogen (0.039 ± 3.88) as shown in Table 3.2. Secondly, dune spinach increased only nitrogen (0.163 ± 6.76) in the SI soil while *soutslaai* increased nitrogen (0.238 ± 10.33), CEC (0.1136 ± 0.10) and zinc (46.5 ± 0.12). Thirdly, dune spinach increased nitrogen (0.106 ± 0.49), zinc (15.9 ± 0.1) and boron (0.48 ± 0.09) for the WEF soil, while *soutslaai* increased nitrogen (0.103 ± 0.45), manganese (48.1 ± 0.12) and

iron (128 ± 0.13).

Soil analysis after the water regime trial showed that dune spinach increased OM in the control (1.46 ± 0.57) and the 25 % (1.32 ± 0.42) water treatments as listed in Table 3.3. It also increased nitrogen, CEC, zinc in the control and at all treatment levels and carbon in the control, 25 % and 80 % treatment levels. Furthermore, dune spinach increased Iron at the control and 25 % water treatment, (7 ± 0.17). *Soutslaai* increased OM in the control 0 % pot capacity (1.15 ± 0.24) and the 50 % pot capacity (1.1 ± 0.18) treatment level; carbon at the control, 25 % and 50 % treatment levels; CEC at the 25 %, 50 % and 80 %, nitrogen and zinc at all water treatment levels. Additionally, the growth of *soutslaai* reduced salinity for soil under the control (0 % pot capacity) and all treatment levels (25 %, 50 % and 80 % pot capacity).

Table 3.2: Characterization of each soil treatment before and after trial of the dune spinach and *soutslaai* growth (significance is indicated by '*', where * is $p > 0.05$)

Parameter	**Kommetjie soil (before trial)**	Dune spinach (after trial)	*Soutslaai* (after trial)	**SI soil (before trial)**	Dune spinach (after trial)	*Soutslaai* (after trial)	**WEF soil (before trial)**	Dune spinach (after trial)	*Soutslaai* (after trial)
pH (KCL)	8.7	8.5	8.7	7.2	7.2	7.5	5.6	**6.9***	**6.4***
Resistance (Ohm)	560	**3960***	**3840***	300	**1240***	**940***	660	**1430***	**1380***
Organic matter (%)	0.93	**1.15***	0.86	4.68	4.47	4.35	3.04	2.99	2.98
P Olsen (mg/kg)	14	1	2	96	30	8	-	-	-
Na (meq/100g)	0.51	0.1	0.08	0.63	0.17	0.22	0.12	0.12	0.21
K (meq/100g)	0.14	0.05	0.04	0.7	0.27	0.41	0.48	0.31	0.41
Ca (meq/100g)	10.26	**10.93***	**11.41***	13.52	**15.41***	**16.16***	6.36	10.48	8.81
Mg (meq/100g)	0.91	0.49	0.7	3.79	2.81	3.69	0.81	0.68	0.84
CEC (meq/100g)	0.0615	0.0593	0.0633	0.1037	0.1019	**0.1136***	0.6903	0.0594	0.053
N (%)	0.008	**0.031***	**0.039***	0.021	**0.163***	**0.238***	0.071	**0.106***	**0.103***
C (%)	0.54	**0.67***	0.50	2.72	2.60	2.53	1.77	1.74	1.73
S (mg/kg)	32.84	16.9	16.5	28.63	14.4	15.1	22.2	11.8	10.9
Cu (mg/kg)	0.3	0.2	0.2	3.4	2.6	3	3.5	2.5	2.9
Zn (mg/kg)	1.7	**2.2***	1.6	41.5	40.7	**46.5***	14.5	**15.9***	15.1
Mn (mg/kg)	1.7	1.4	1.2	16.8	11.9	12.4	42.8	38.2	**48.1***
B (mg/kg)	0.74	0.5	0.53	1.37	1.1	1.15	0.44	**0.48***	0.42
Fe (mg/kg)	6	5	5	79	77	78	113	88	**128***

Table 3.3: Characterization of each water regime before and after trial of dune spinach and *soutslaai* growth (significance is indicated by '*', where * is $p > 0.05$)

		Dune Spinach				***Soutslaai***			
Parameter	**Kommetjie soil (before trial)**	Control (no watering)	25 % pot capacity	50 % pot capacity	80 % pot capacity	Control (no watering)	25 % pot capacity	50 % pot capacity	80 % pot capacity
pH (KCL)	8.7	8.5	8.7	8.8	8.7	8.8	8.6	8.6	8.5
Resistance (Ohm)	560	**1380***	**1930***	**1120***	**2820***	**1070***	**1720***	**2650***	**2880***
OM (%)	0.93	**1.46***	**1.32***	0.84	0.98	**1.15***	0.98	**1.1***	0.71
P Olsen (mg/kg)	14	1	2	**17***	**19***	4	3	2	2
Na (meq/100g)	0.51	0.2	0.14	0.35	0.1	0.31	0.09	0.11	0.1
K (meq/100g)	0.14	0.06	0.05	0.08	0.05	0.08	0.05	0.05	0.05
Ca (meq/100g)	10.26	12.85	11.54	11.17	12.19	10.34	11.65	13.03	12.9
Mg (meq/100g)	0.91	0.77	0.62	0.85	0.73	0.8	0.6	0.66	0.7
CEC (meq/100g)	0.0615	**0.0717***	**0.0636***	**0.0647***	**0.0676***	0.0599	**0.0638***	**0.0713***	**0.0709***
N (%)	0.008	**0.037***	**0.041***	**0.047***	**0.044***	**0.04***	**0.1***	**0.044***	**0.046***
C (%)	0.54	**0.85***	**0.77***	0.49	**0.57***	**0.67***	**0.57***	**0.64***	0.41
S (mg/kg)	32.84	27.4	22.4	23.5	18.8	23.8	21.6	21.6	20.3
Cu (mg/kg)	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Zn (mg/kg)	1.7	**2.8***	**2.7***	**2***	**2.2***	**2.1***	**2.1***	**1.9***	**1.9***
Mn (mg/kg)	1.7	1.7	1.5	1.3	1.3	1.4	1.3	1.1	1.2
B (mg/kg)	0.74	0.55	0.59	0.72	0.5	0.64	0.59	0.59	0.56
Fe (mg/kg)	6	7	7	5	6	6	6	5	5

Figure 3.2: Top left: *soutslaai* seeds and pods; top right: *soutslaai* seedlings at 4 days; bottom left: *soutslaai* seedlings at 10 days; bottom right: *soutslaai* seedlings at 3 weeks

3.3.2 Agronomic Performance

Data is presented as mean ± standard deviation unless otherwise stated. Multiple comparison tests were only conducted if the result was found to be statistically significant. The non-parametric Kruskal-Wallis was used only if the normality assumption was violated by more than one treatment group. Detailed statistic results shown in Appendix A.

3.3.2.1 Germination and Growth Stages of *M. crystallinum* (*soutslaai*)

Figure 3.2 gives a visual illustration of plant development of the mass germination carried out in the SI soil to provide seedlings for the experiment. Only the *soutslaai* was propagated from seed. Seeds germinated easily within 3 to 10 days in the coastal dune sands and sandy SI soils in the late March and Early April. *Soutslaai* germinated quickly and subsequent germination occurred even 6 weeks and 8 weeks after planting. Plant development in the sandy dune soils and SI soils progressed quickly while *soutslaai* seedlings and the rooted cuttings struggled to establish themselves in the WEF soils.

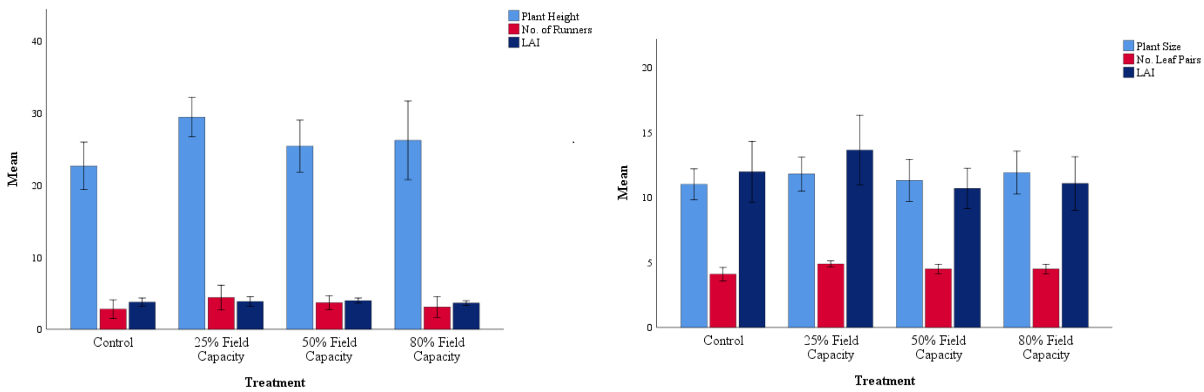
3.3.2.2 Irrigation Treatment Growth Parameters

Plant height, number of runners and leaf area index (LAI) for dune spinach and plant size of *soutslaai*, number of leaf pairs and LAI were not significantly affected by the varying water treatments as depicted in Table 3.4. However, the general trend was that plant height and number of dune spinach runners were higher for the 25 % water treatment while dune spinach LAI was highest for the 50 % water treatment in Figure 3.3a, while the number of *soutslaai* leaf pairs and LAI were highest for the 25 % water treatment, and plant size was highest at the 80 % water treatment in Figure 3.3b.

Table 3.4: Means of growth responses across varying irrigation treatments for dune spinach and *soutslaai*

Cape Wild Vegetable	Parameters	Control	25 % Pot Capacity	50 % Pot Capacity	80 % Pot Capacity	ANOVA p-value
Dune Spinach	Plant Height (m)	0.23[a]	0.29[a]	0.25[a]	0.26[a]	0.066
	No. of Runners	2.80[a]	4.40[a]	3.70[a]	3.10[a]	0.279
	LAI	3.77[a]	3.86[a]	3.98[a]	3.64[a]	0.503
SoutSlaai	Plant Size (cm)	11.03[a]	11.82[a]	11.33[a]	11.93[a]	0.73
	No. of Leaf Pairs (mean ranks)	4.1[a]	4.9[a]	4.5[a]	4.5[a]	0.39
	LAI	11.99[a]	13.66[a]	10.71[a]	11.09[a]	0.162

Note: Means with same letters are not statistically significant



(a) (b)

Figure 3.3: Means of growth responses across water treatments for (a) dune spinach and (b) *soutslaai*.

3.3.2.3 Irrigation Treatment Biomass Accumulation

Fresh mass of dune spinach shoot, leaves, and the dry mass of leaves were statistically significant across the varying water treatment levels as tabulated in Table 3.5, $p < 0.05$. The highest means for fresh mass of whole dune spinach plant, shoot, root and leaves were obtained under the dune spinach plants that received no water as shown in Figure 3.4a. The lowest means were obtained under the 25 % water treatment level. The highest means for dry mass of leaves were obtained under the 50 % water treatment level. Only fresh mass of *soutslaai* leaves were significant across the water treatment levels as shown in Table 3.5, $p = 0.05$. However, the means for fresh mass of whole *soutslaai* plants, shoot, root, leaves and dry mass of leaves were highest at the 25 % as displayed in Figure 3.4b.

Table 3.5: Means of biomass accumulation across varying irrigation treatments for dune spinach and *soutslaai*

Cape Wild Vegetable	Plant Parts (g/plant)	Control	25 % Pot Capacity	50 % Pot Capacity	80 % Pot Capacity	ANOVA p-value
Dune Spinach	FM whole plant	23^{a}	16.18^{a}	19.96^{a}	19.1^{a}	0.088
	FM shoot (mean rank)	10.58^{a}	7.14^{ab}	10.26^{ac}	10.01^{a}	Kruskal-Wallis **0.013**
	FM root	13.12^{a}	8.98^{a}	9.48^{a}	10.03^{a}	0.454
	FM leaves (mean rank)	7.27^{a}	4.67^{ab}	6.91^{ac}	7.27^{ad}	Kruskal-Wallis **0.009**
	DM leaves	0.78^{a}	1.21^{ab}	1.41^{ac}	1.22^{ad}	**0.005**
	DM Root/Shoot ratio	1.43^{a}	1.06^{a}	1.04^{a}	1.07^{a}	0.135
Soutslaai	FM whole plant	15.86^{a}	21.19^{a}	15.62^{a}	15.78^{a}	0.175
	FM shoot	13.97^{a}	17.35^{a}	12.37^{a}	13.25^{a}	0.109
	FM root	1.85^{a}	3.65^{a}	2.91^{a}	2.53^{a}	Kruskal-Wallis 0.118
	FM leaves	11.51^{a}	14.48^{ab}	9.39^{ac}	10.19^{a}	**0.042**
	DM leaves	0.96^{a}	1.22^{a}	0.82^{a}	0.89^{a}	0.146
	DM Root/Shoot ratio	0.25^{a}	0.26^{a}	0.3^{a}	0.23^{a}	0.545

Note: Means with the same letter are not significantly different, FM = fresh mass, DM = dry mass

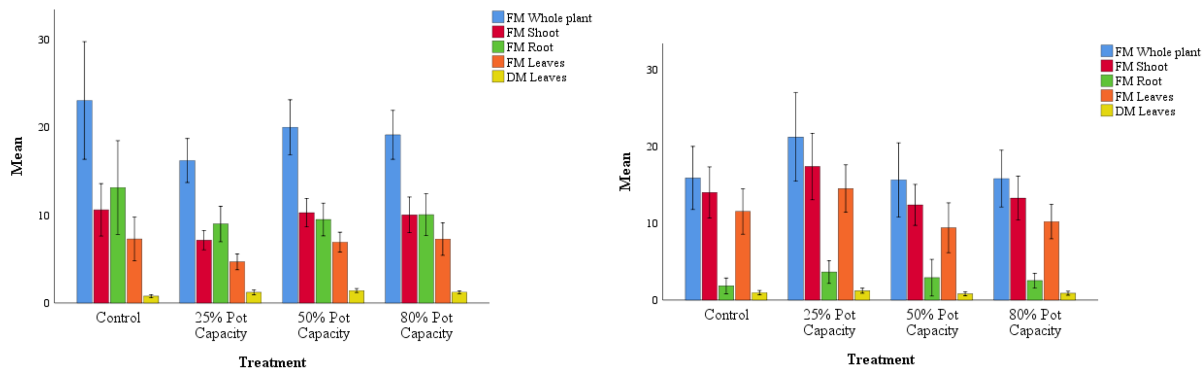


Figure 3.4: Means for biomass accumulation across water treatments for (a) dune spinach and (b) *soutslaai*

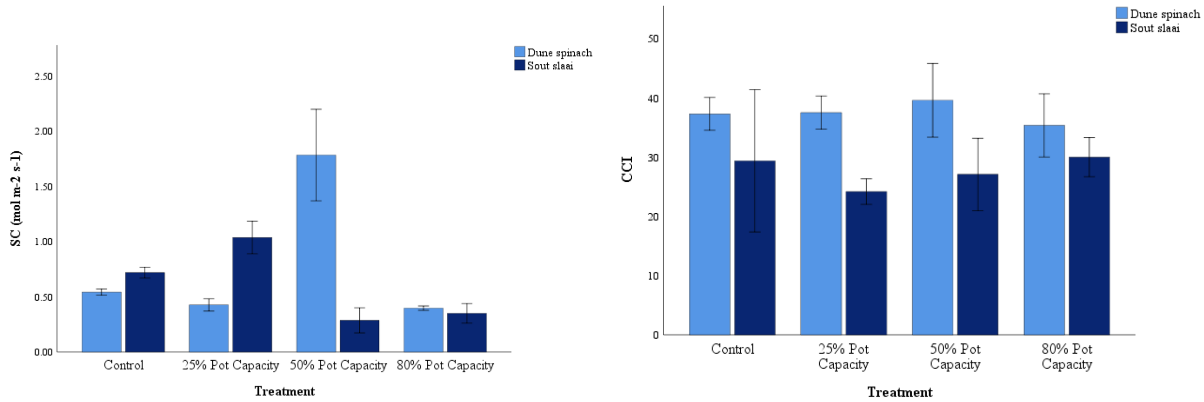
3.3.2.4 Irrigation Treatment Physiological Parameters

Stomatal conductance (SC) for both dune spinach and *soutslaai* were statically significant for the varying water treatments as shown in Table 3.6. Highest treatment means for dune spinach SC where obtained under the 50 % PC treatment while for *soutslaai* highest means were obtained under 25 % PC as displayed in Figure 3.5a. On the other hand, Figure 3.5b showed that chlorophyll content index (CCI) was only statistically significant for *soutslaai* but not for dune spinach across the treatment levels.

Table 3.6: Means of physiological responses across varying irrigation treatments for dune spinach and *soutslaai*

Cape Wild Vegetable	Parameters	Control	25 % Pot Capacity	50 % Pot Capacity	80 % Pot Capacity	p-value (0.05)
Dune spinach	SC (mol m−2 s−1)	0.54^{a}	0.43^{b}	1.78^{ab}	0.40^{b}	< 0.001
	CCI	37.3^{a}	37.52^{a}	39.59^{a}	35.37^{a}	0.535
SoutSlaai	SC (mol m−2 s−1)	0.72^{a}	1.04^{b}	0.29^{cd}	0.35^{cd}	< 0.001
	CCI	29.37^{a}	24.2^{a}	27.1^{ab}	30.01^{ac}	0.033

Note: Means with same letters are not statistically significant



(a) (b)

Figure 3.5: Means of physiological response for across varying water for dune spinach and *soutslaai:* (a) Stomatal conductance (SC) and (b) Chlorophyll content index (CCI)

3.3.2.5 Soil Treatment Growth Parameters

Plant height, plant size, and LAI for dune spinach and *soutslaai* showed statistically significant increases ($p < 0.05$) from the control when subjected to the two soil treatments as tabulated in Table 3.7. Highest means for dune spinach height, number of runners and LAI were observed for the SI soils as depicted in Figure 3.6a. Figure 3.6b illustrates that *soutslaai* plant size, LAI, and number of leaf pairs where highest under the plants grown in the SI soils, though not significant for the number of leaf pairs.

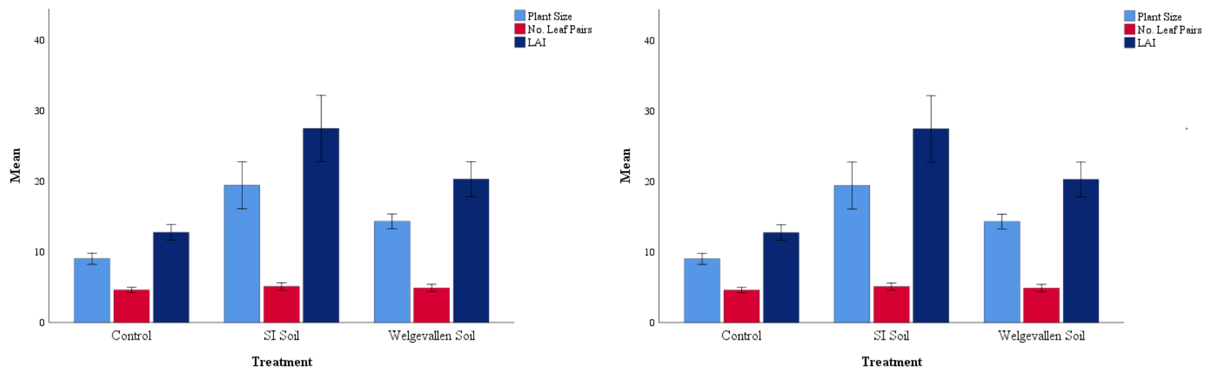
3.3.2.6 Soil Treatment Biomass Accumulation

Table 3.8 demonstrates how biomass accumulation, the fresh mass of the whole dune spinach plant, shoot, root, and leaves were statistically significant across the soil treatments and control, $p < 0.001$. The same was true for the *soutslaai*, except for the fresh mass of its roots which was not statistically significant. Dry mass of leaves and root to shoot ratio were statistically significant for both dune spinach and *soutslaai*. Highest biomass accumulations were obtained under the SI soil treatment level for both vegetables as shown in Figure 3.7.

Table 3.7: Means of physiological responses across varying irrigation treatments for dune spinach and *soutslaai*

Cape Wild Vegetable	Parameters	Control	SI Soil	WEF Soil	ANOVA *p*-value
	Plant Height (m)	0.24^{a}	0.43^{b}	0.19^{c}	**<0.001**
	No. of Runners	3.8^{a}	5.8^{a}	4.1^{a}	0.082
Dune Spinach	LAI	2.59^{a}	7.73^{b}	7.64^{b}	**<0.001**
	Plant Size (cm)	9.05^{a}	19.45^{b}	14.33^{b}	**0.018**
	No. of Leaf Pairs (mean ranks)	4.6a	5.1a	4.9a	Kruskal-Wallis 0.28
Soutslaai	LAI	12.76^{a}	27.5^{b}	20.31^{c}	**<0.001**

Note: means with same letters are not significantly different

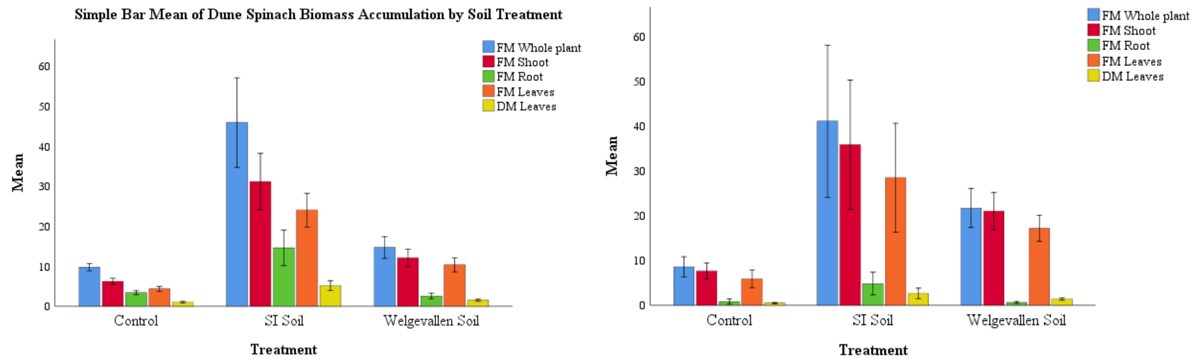


(a) (b)

Figure 3.6: Means of growth responses for dune spinach (a) and *soutslaai* (b) across soil treatments

Table 3.8: Means of biomass accumulation across varying soil treatments for dune spinach and *soutslaai*

Cape Wild Vegetable	Plant Parts (g/plant)	Control	SI Soil	WEF Soil	p-value
Dune spinach	FM whole plant	9.78^{a}	45.88^{b}	14.70^{c}	**< 0.001**
	FM shoot	6.22^{a}	31.15^{b}	12.08^{c}	**< 0.001**
	FM root	3.39^{a}	14.60^{b}	2.59^{ac}	**< 0.001**
	FM leaves	4.35^{a}	24.03^{b}	10.34^{c}	**< 0.001**
	DM leaves	1.01^{a}	5.18^{b}	1.54^{c}	**< 0.001**
	DM Root/Shoot ratio	0.80^{a}	0.81^{a}	0.33^{b}	**< 0.001**
Soutslaai	FM whole plant	8.60^{a}	41.14^{b}	21.74^{b}	**< 0.001**
	FM shoot	7.66^{a}	35.92^{b}	21.04^{b}	**< 0.001**
	FM root	0.84^{a}	4.84^{b}	0.64^{a}	**0.009**
	FM leaves	5.90^{a}	28.52^{b}	17.20^{b}	**< 0.001**
	DM leaves	0.50^{a}	2.66^{b}	1.38^{b}	**< 0.001**
	DM Root/Shoot ratio	0.26^{a}	0.39^{a}	0.11^{b}	**< 0.001**



(a) (b)

Figure 3.7: Means of growth responses for dune spinach (a) and *soutslaai* (b) across soil treatments

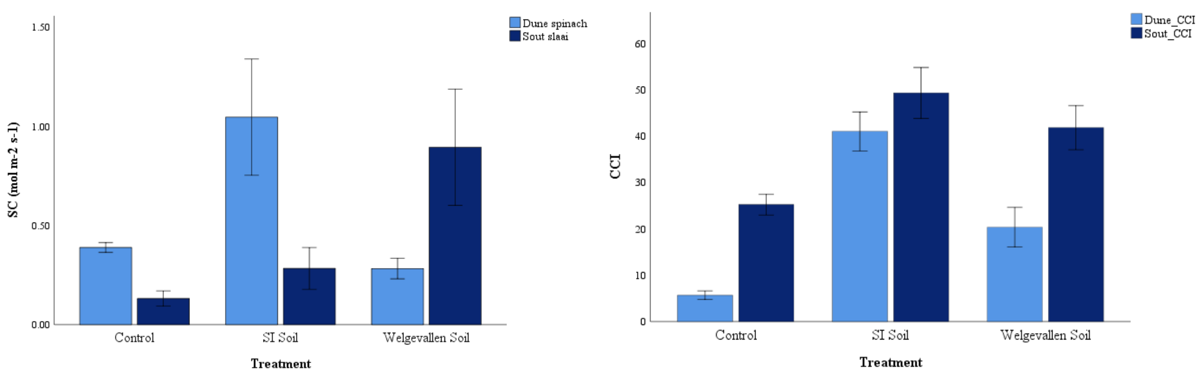
3.3.2.7 Soil Treatment Physiological Parameters

Stomatal conductance and chlorophyll content index were statistically significantly different for both dune spinach and *soutslaai* as shown in Table 3.9, $p < 0.001$. The highest levels of SC and CCI were obtained from the plants growing in the SI and WEF soils as displayed in Figure 3.8.

Table 3.9: Means of biomass accumulation across varying soil treatments for dune spinach and *soutslaai*

Cape Wild Vegetable	Parameters	Control	SI Soil	WEF Soil	*p*-value *(0.05)*
Dune Spinach	SC (mol m−2 s−1)	0.39^{a}	1.04^{b}	0.28^{c}	<0.001
	CCI	5.66^{a}	40.98^{b}	20.32^{c}	< 0.001
Soutslaai	SC (mol m−2 s−1)	0.13^{a}	0.28^{b}	0.89^{c}	<0.001
	CCI	25.2^{a}	49.27^{bd}	41.79^{cd}	<0.001

Note: means with different numbers are significantly different

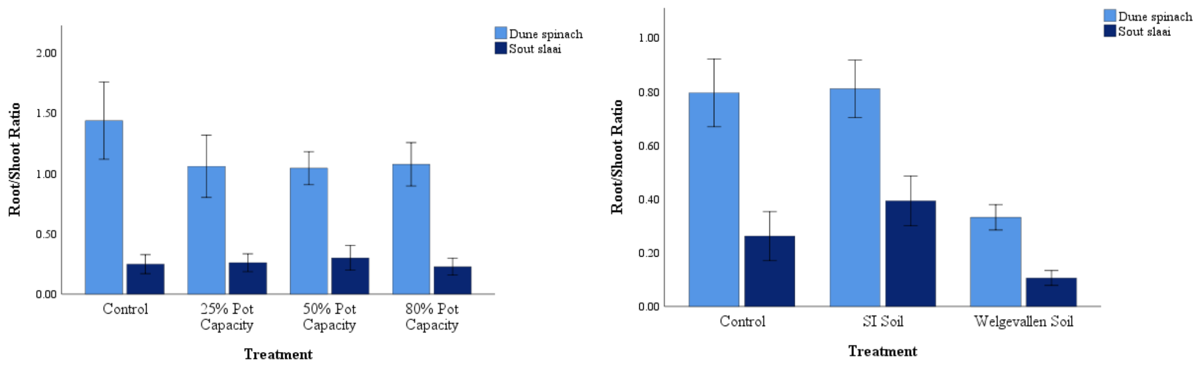


(a) (b)

Figure 3.8: Means of SC (a) and CCI (b) for dune spinach and *soutslaai* across soil treatments

3.3.2.8 Root to Shoot Ratio

Root to shoot ratio were not significantly affected by water treatment level for both the dune spinach and *soutslaai* as seen in Table 3.5, $p > 0.05$. They ranged from 1.04 to 1.43 for dune spinach and 0.23 to 0.3 for *soutslaai* with the highest means being obtained at the no watering level for dune spinach and the 50 % water level for *soutslaai*. On the contrary, there were significant differences in root to shoot ratio for the varying soil treatments for both dune spinach and *soutslaai* as tabulated in Table 3.8 and displayed in Figure 3.9, $p < 0.001$. The highest ratios were obtained in the control and SI soil treatment for the dune spinach and the SI treatment for the *soutslaai*.



(a) (b)

Figure 3.9: Means of root to shoot ratio for (a) varying water treatments and (b) varying soil treatments for dune spinach and *soutslaai*

3.4 Discussion

This study investigated the agronomic performance of two wild edible fynbos species indigenous to the Western Cape, *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*).

Due to the small sample size, results from the study can not be generalised but instead a conservative extrapolation of these preliminary results is made within the limitations of the study. The results of the soil analysis tabulated in Tables 3.2 and 3.3 for both the water and soil regime trials suggest that *soutslaai* and dune spinach can help increase soil organic matter, carbon, CEC, nitrogen and micronutrients such as iron, zinc, boron and manganese. Greater nutrient availability has been reported as a consequence of the use of halophytes to reclaim saline and sodic soils for agricultural use (Hasanuzzaman *et al.*, 2014). Therefore, it is possible that there was an increase in the presence of some nutrients. Notably, the effect that irrigation has on depleting soils nutrients was not accounted for and consequently, further work is needed to investigate the leachate from potted experiments on indigenous halophytes to consider minerals being lost through irrigation. Both dune spinach and *soutslaai* increased the soil resistance when before and after results of the soil analysis were compared. This increase in resistance indicates a reduction in salt concentration as shown in Tables 3.2 and 3.3. Consequently, dune spinach and *soutslaai* seem to have reduced the soil salinity of the soils used in the study. This corresponds with studies by Balakrishnan (2007) and Cassaniti and Romano (2011) supporting the use of halophytes for landscape restoration and to remediate salt affected areas because of their adaptive mechanisms that can withstand and utilise salt and other toxic minerals. Other studies support this function of halophytes (Villiers *et al.*, 1995; Yen *et al.*, 1995; Hegazy, 1997; Shevyakova *et al.*, 2003; Ghnaya *et al.*, 2005; Agarie *et al.*, 2007). The adaptive nature of dune spinach and *soutslaai* to be salt tolerant therefore opens the door for the utilization of marginal water such as sea water for food production (Herppich and Schreiner, 2008). Hasanuzzaman *et al.* (2014) has reported both *M. crystallinum* (*soutslaai*) and *T. tetragonoides* (New Zealand spinach) as some of the halophytes having the highest potential for irrigation with saline water. This may also be due to the high turnover resulting from halophytic communities such as dune spinach and *soutslaai* dominating over salty soils that salt intolerant plants cannot withstand as discussed by Wendelberger and Richards (2017).

The results of this study, visually represented in Figure 3.2, demonstrated that *soutslaai* germination is relatively easy on sandy soils but struggled to germinate in the loam soil. Only the *soutslaai* was propagated from seed and germinated easily three months earlier than expected in the wild. Plant development from germination to four weeks progressed as reported in literature and it must be noted that seedlings do not cope well under stress and so should be well watered in the beginning (Adams *et al.*, 1998). From time of planting it should be expected that seedlings will be ready for transplanting between three to four weeks. However, Rusch (2016) noted that propagating *soutslaai* in the field from seed had been problematic in April, that is, before the winter rains (Rusch, 2016). Snails were also identified as natural pests for *soutslaai* seedlings and consequently wild seedlings were eventually used. Propagation has also been successful on *soutslaai* vegetative plant parts (Watkins *et al.*, 1988; Rusch, 2016). Furthermore, Rusch (2016) recommended that transplanting of seedlings be done before the winter rains begin. Based on this and the current study, the recommended planting and transplanting dates are between March and June.

Germination tests were done on both *soutslaai* and dune spinach seeds (results not shown). Germination percentage was very low for dune spinach and even *soutslaai*, which was surprising considering how well *soutslaai* performed in the farm tunnel used during the trial. The low germination percentages did not improve with the use of smoke primers commonly used to enhance germination rates for fynbos seeds. It may be that salt conditions are necessary to break seed dormancy as these are coastal species. Successful seed germination has been carried out in half strength Hoagland's solution and nitrate soaked vermiculite (Watkins *et al.*, 1988; Adams *et al.*, 1998; Agarie *et al.*, 2007).

The results of growth response and biomass accumulation for both dune spinach and *soutslaai* are consistent with literature that shows that indigenous vegetables are well adapted to drought conditions and might even grow better with minimal water quantities (Villiers *et al.*, 1995; Hegazy, 1997; Slabbert *et al.*, 2004; Abanda *et al.*, 2011; Cecilio Filho *et al.*, 2017). The trials showed that when dune spinach and *soutslaai* are grown in the soil in which they naturally occur, the amount of water they are exposed to has no significant effect on the growth responses. This may be due to the lack of enough nutrients that may have leached out over time in the constraints of a pot. The size of the pot may also have contributed to this result as the case might have been different if the plants roots were exposed to a more extensive soil system.

Plant growth and biomass accumulation of dune spinach and *soutslaai* did not differ significantly under the varying water treatments as shown in Table 3.4 and Table 3.5. Naturally this demonstrates a show of resilience to scarce water conditions. More literature exists on halophyte's responses to salt tolerance than on their agronomic response to drought conditions. However, both are stresses that are mitigated by the same adaptive traits in halophytes which include CAM photosynthesis (Bohnert and Cushman, 2000; Medrano *et al.*, 2009).
Dune spinach plant height, *soutslaai* plant size, and LAI for dune spinach and *soutslaai* were significantly affected by the varying soil treatments as illustrated in Figure 3.3. The highest means were obtained from the SI soils for both dune spinach and *soutslaai*. Though there was no statistical significance between the means of number of dune spinach runners and *soutslaai* leaf pairs, the greatest means were obtained under the SI soils. Fresh mass of whole dune spinach plant, shoot, root, leaves, and dry mass of leaves were statistically significant across the varying soil treatment levels. Figure 3.4 depicts that the highest means were obtained under the SI soil treatment and the lowest means were obtained in the control experiment. This suggests that the best soil to grow both vegetables is sandy soil that is enriched with essential nutrients and organic matter. This corresponds with studies showing positive agronomic responses by indigenous vegetables when exposed to basic production practices (Herppich and Schreiner, 2008; Mavengahama, 2013; Cecilio Filho *et al.*, 2017).

Both dune spinach and *soutslaai's* growth responses where better for the SI soil than the soils in which they naturally occur as shown in Figure 3.3. The results suggest that if a loam soil is used, water-logging is to be avoided and with occasional manual root aeration. Subsequent studies would need to be carried out on the quantity of nutrients needed to increase agronomic performance. Figure 3.9b illustrates how the root to shoot ratio data suggests that while nutrient availability and organic matter content is important in increasing biomass accumulation, soil texture may also be equally or more important for these sand loving vegetables (Abanda *et al.*, 2011). Even so, the higher fertility level of the WEF soil compared to the coastal soils, based on soil characterization in Appendix F, is not as weighty as the effect of soil texture on dune spinach in particular. This corresponds to literature that indicated that fynbos plants generally struggle to thrive in heavier soils such as loamy and clayey soils (Esler *et al.*, 2015). Root to shoot ratio is an indication of the health of the plant and resource availability for plant growth. The results of the root to shoot ratio correspond with the physical observations made during the trial as well as the soil characterization. CAM photosynthesis allows halophytes such as dune spinach and *soutslaai* to close some or most of their stomata during day time to avoid losing water and only open them up at night thus being an efficient adaption for water use. However this adaptation is not limited to halophytes. Lotter *et al.* (2014) observed a decrease in stomatal conductance of *Aspalathus linearis* (*rooibos*), a fynbos legume, under drought stress and two other studies on selected C3 Meditarranean plants also showed similar results (Medrano *et al.*, 2002, 2009).However this was not the case with the results of the present study whose highest final stomatal conductance mean was collected under the 50 % water treatment for dune spinach and 25 % treatment for the *soutslaai*. More research is needed to investigate trends in stomatal conductance and water-use efficiency of halophytes like these.

Stomatal conductance was significant for all soil treatments for both dune spinach and *soutslaai* as displayed in Figure 3.8a. A study on cotton and bean leaves showed that salinity decreased stomatal conductance (Brugnoli and Lauteri, 1991). Contrary to this study, the highest SC measured was for the dune spinach growing in the SI soil which had the highest indication of salinity. On the other hand, the highest SC measured for the *soutslaai* was that growing in the WEF soil. This may be an indication that dune spinach is less sensitive to salinity when compared to *soutslaai*. We suggest that this is because of the better water holding capacity of the WEF and SI soil compared to the coastal sand. This may explain the low SC levels in the Kommetjie dune soils. Chlorophyll content index (CCI) for both dune spinach and *soutslaai* were not statically significant for the varying water treatments ($p > 0.05$), though means were highest in the SI soil. This may have been because of higher organic matter content and micronutrient composition of the SI soil. CCI was not statistically significant for dune spinach for the varying water treatment levels however, it was significant for *soutslaai* and highest at the 80 % water treatment.

3.5 Conclusion

While the results of the study are not be be generalised due to the small sample size, a conservative extrapolation of the study in addition to literature deduce that *T. decumbens* and *M. crystallinum* are well suited as agronomic resources in the Western Cape region. Firstly, their halophytic nature makes them ideal crop alternatives for growers experiencing effects of climate change that include both very high and low temperatures, drought and increasing soil salinity. Both species utilised less than half of the water that was required for plant growth within the study. This demonstrated the expected high tolerance to drought conditions rendering them appropriate alternative minimal water-utilizing plants. Secondly, these edible fynbos species have the potential to remediate saline and sodic soils for agrarian uses. The study showed a potential for dune spinach and *soutslaai* to increase certain soil nutrients or make them more available in the soil for plant use. Thirdly, they have the potential to produce abundant biomass while utilising marginal soils and irrigation water. Potential for very high yield exists with the addition of nutrients. Biomass accumulation can increase under saline conditions.

Lastly, these species possess antimicrobial properties that potentially aid in making them resilient towards pests, fungal infections and disease. This is beneficial for economically resource-poor growers who would not need to invest too much capital in plant protection options. Furthermore, there antioxidant properties and potential to amass micronutrients make them sustainable and viable sources of food and nutrients. They possess medicinal and health benefits that can also be utilized.

3.6 Bibliography

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Chapter 4

Exploring Potential Consumer Acceptance of *Tetragonia decumbens* and *Mesembryanthemum crystallinum*

Abstract

Twenty-four respondents participated in a survey that explored their acceptance of two edible fynbos plant species: *Tetragonia decumbens* (dune spinach) and *Mesembryanthemum crystallinum* (*soutslaai*). These plants are indigenous to the coastal Cape fynbos in the Western Cape of South Africa with potential use as alternative vegetables and sources of nutrition though not widely known as such. A convenience sample ($n = 24$) comprised a group of 11 senior Conservation Ecology university students and 9 community members of the Sustainability Institute (SI) in Lynedoch, Stellenbosch. Each of the two species were prepared as greens in a raw salsa and a braise (or *smoortjie*[1] in Afrikaans). An acceptability score for each wild vegetable in its cooked and raw form was measured on a five-point hedonic scale and aggregated into an overall acceptability score for both indigenous Cape wild vegetables. An analysis of variance revealed that the dune spinach *smoortjie* had a significantly higher median score of acceptability compared to the raw dune spinach salsa ($p = 0.035$). On the contrary, the *soutslaai smoortjie* did not generate a statistically significant median increase in acceptability compared with the *soutslaai* salsa ($p = 0.092$). Consumption and purchasing intent for both vegetables were measured. A correlation analysis revealed that if people accepted the dune spinach vegetable, they were likely to accept the *soutslaai* vegetable, $r(23) = 0.504$, $p = 0.01$. There was no association between consumption intent and overall acceptance of the two indigenous vegetables, $r(23) = 0.362$, $p = 0.082$. However, there was a strong positive association between the respondents' overall acceptance of the two indigenous vegetables and their purchasing intention, $r(23) = 0.698$, $p < 0.01$. The most important reasons for purchasing these indigenous vegetables that emerged was the frequency of vegetable purchase and the economics around the vegetables such as availability, price and scarcity.

Keywords: Cape wild vegetables; acceptability; consumption intent

4.1 Introduction

Consumer studies on the adoption and acceptance of indigenous vegetables have not been widely investigated. This may be because it is only recently that utilisation of indigenous

[1] A *smoortjie* is a braise or stew. Consists of light frying of meat or vegetables in an onion and tomato base sauce and slow stewing.

foods, also referred to as orphan crops, has received attention as a food insecurity and climate change mitigation strategy (Slabbert *et al.*, 2004; Heywood, 2011; Bvenura and Afolayan, 2015; Phiri and Mothapo, 2017). For the purposes of this research, wild vegetables will refer to edible plants commonly collected and/or semi-cultivated for their nutritional value to humans. These wild vegetables are used as a side dish or relish and are good sources of fibre, minerals, vitamins and other bioactive compounds (Agudo, 2005). Wild leafy vegetables will refer to edible plant species, that are native to their environments and not in cultivation, whose leaves, young stems and fruit and sometimes flowers are utilized as food by local communities (Jansen van Rensburg *et al.*, 2007).

This study focused on two edible plant species indigenous to the Cape fynbos *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*), and will hereafter be collectively referred to as Cape wild vegetables. A description of these two species has been given in Section 2.3. Most of the research around vegetables so far has focused on trying to increase consumption through providing nutritional information and health benefits of vegetable intake (Ruel *et al.*, 2005; Agudo, 2005; Pomerleau *et al.*, 2005; Tiwari and Cummins, 2013; Heinrichs and Ellison, 2016). Health benefits include the potential to reduce the risk of chronic and communicable diseases, cancer, minimising micro-nutrient deficiencies, decreasing the rate of obesity, and weight management. With the recommended daily consumption of fruit and vegetables at 400g per individual per day, various interventions have been carried out to increase consumption particularly in developing countries (WHO, 2003; Agudo, 2005; Jemmott *et al.*, 2011; Hansen, 2012; Tiwari and Cummins, 2013; Backeberg, 2014). Despite this information, vegetable consumption is still a significant problem in sub-Saharan Africa (Ruel *et al.*, 2005; WHO, 2011).
According to a press release by Backeberg (2014), South Africans are not consuming the required amounts of fruits and vegetables, despite the availability of diverse indigenous leafy vegetables. These vegetables have been shown to be rich in fibre and micro-nutrients when compared to conventional vegetables such as Swiss chard and cabbage, some providing more than 50 % of vitamin A required daily (Backeberg, 2014; Mavengahama *et al.*, 2014; Bvenura, 2014). Available nutritional information on *soutslaai* and New Zealand spinach, an analogue for dune spinach, is provided in Section 2.3.3.
Furthermore, some wild leafy vegetables are also more heat and drought tolerant (Slabbert *et al.*, 2004; Backeberg, 2014; FAO, 2014). Rural communities in particular, depend on foraging seasonal and underutilized indigenous vegetables, for dietary support (Jansen van Rensburg *et al.*, 2007; Chivenge *et al.*, 2015). Three of the most popular leafy indigenous vegetables (also referred to as *morogo* or *imifino* [1]) include the *Amaranthus cruentus* (Amaranthus/pigweed), *Bidens pilosa* (blackjack) and *Vigna unguiculata* (cowpea). These vegetables are still only a focus for research as potential solutions to food and nutrition security in the South African context as opposed to being available in the local food system alongside more conventional vegetables. Absence from mainstream markets has not helped reduce further decline in the utilisation of these species. In their investigation of dietary diversity and vegetable and fruit consumption

[1] *Morogo* and *imifino* are collective local terms in seSotho and isiZulu used for African leafy vegetables.

in relation to food security, Faber *et al.* (2017) themselves admit having left out African leafy vegetable consumption in determining the fruit and vegetables consumed by both food secure and insecure families.

Lack of knowledge about wild leafy vegetables as well as the perception of poor taste are two of the biggest hindrances to their adoption (Bvenura and Afolayan, 2015). In addition to this, research funds have mostly been directed into commercial crops such as cereal cash crops and exotic vegetables which has not inspired any commercial vegetable growers to consider indigenous vegetables as viable alternatives (Phiri and Mothapo, 2017). Consequently, some edible wild vegetables are negatively perceived as weeds and pest carriers by large scale vegetable growers (Mavengahama, 2013). However, subsistence farmers that utilise some of these wild vegetables keep them alongside their value crops. An additional hindrance to adoption is the association of wild leafy vegetables with poverty, particularly in some rural and peri-urban South African communities, thus further under-valuing and under-utilising them (Venter *et al.*, 2007; Ndwandwe, 2013; Mavengahama, 2013; Backeberg, 2014; Bvenura and Afolayan, 2015; Lindow, 2017). Furthermore, the inadequate depth of information about the nutritional qualities of these vegetables does not promote consumption amongst communities whose consumption is informed by their perception and knowledge of a food's nutritional status.

As the use and documentation of indigenous knowledge around indigenous foods is generated, there grows potential for some of these wild vegetables to break onto the market due to consumer demand, as has been witnessed in other African countries (Bvenura and Afolayan, 2015; Lindow, 2017; De Bruin, 2018). While very few studies exist to investigate potential consumer response to unknown or underutilised wild vegetables in the Western Cape, there is a growing body of wild food enthusiasts and chefs that incorporate wild foods into their cuisines (Lindow, 2017; Van der Merwe and De Villiers, 2014).

Understanding the consumers' perceptions of indigenous edible foods in general can give insights into how to promote their utilisation. This is because consumption and purchasing intention are two of the most important factors in determining if a food might be adopted. Furthermore, appearance and taste are also a big part of the consumer adoption process (Barrett *et al.*, 2010; Heinrichs and Ellison, 2016). Studies in some parts of South Africa show that while taste is a huge motivator to eat indigenous foods, for others it is taste that demotivates consumption (Jansen van Rensburg *et al.*, 2007; Vorster, 2007; Mavengahama, 2013; Bvenura, 2014; Bvenura and Afolayan, 2015). Therefore, research promoting improvements in palatability of wild edible species is necessary to encourage consumer adoption. In addition to sensory attributes, factors such as convenience, cost, society, heritage, health and availability, among others, also heavily influence consumer adoption and preference for indigenous vegetables (Cook, 2016; Heinrichs and Ellison, 2016).

Indigenous vegetables have a role to play in promoting more resilient food systems, sustainable food choices, responsible consumption and environmental conservation, social well-being, food sovereignty, and nutrition security. If wild indigenous leafy vegetables such as (*T. decumbens*) dune spinach and (*M. crystallinum*) *soutslaai* are to live up to these claims, barriers to their

utilization, production and adoption will have to be overcome.
The aim of this chapter is to explore potential consumer acceptance and consequent adoption of two indigenous wild vegetables that occur in the Western Cape; i.e. (*T. decumbens*) dune spinach and (*M. crystallinum*) *soutslaai*. Specifically, the chapter investigates the general perceptions of indigenous vegetables, the acceptability of the dune spinach and *soutslaai* in their cooked and raw forms as well as the intended future consumption.

4.2 Methodology

4.2.1 Geographical Location

A tasting event took place at the Sustainability Institute (SI) in Lynedoch, Western Cape, South Africa (33.9826 °S, 18.7687 °E) as shown in Figure 3.1. The SI was a research-based eco-village that consists of a pre-school, primary school, university students, and a working community. Like the rest of the Western Cape, the SI experiences a Mediterranean climate with winter rainfall occurring between the months of April and September. The study was carried out at the SI due to its proximity to the Stellenbosch University and the indigenous gardens it supports at which both species investigated in this chapter grow.

4.2.2 Food Preparation and Presentation

Two recipes of each vegetable where prepared, one raw and the other cooked, and presented to respondents as illustrated in Figure 4.1. The raw recipe was referred to as the salsa while the cooked/braised recipe was the *smoortjie*. These were prepared by Ms. Loubie Rusch, an indigenous food activist and chef. Recipes are tabulated in Table B.1 (Appendix B). Fresh plant samples of both dune spinach and *soutslaai* were placed on each table for respondents to see, touch and smell. The food was presented in 50ml shot glasses and respondents where provided with glasses of water to drink before and in between each tasting (Figure 4.2). Serviettes were provided to clean the 50 ml shot glasses provided for the food samples before and after each tasting. No nuts or gluten were added to the dishes prepared. This was also declared in the consent form.

4.2.3 Ethical Considerations

Ethical clearance was obtained from the Stellenbosch University's Humanities Research Ethics Committee (7149). Consent forms were signed before the survey commenced. It was communicated to respondents that they were not obligated to participate in the survey and there would be no negative consequences if they did not participate. Respondents were informed that they would not be paid for participating and their information will be handled with respect and confidentiality.

4.2.4 Survey

A convenience sample of 24 respondents were invited to take part in a survey that assessed their acceptance of two edible fynbos plant species: *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*). A group of 11 senior Conservation Ecology students and 2 staff members from Stellenbosch University as well as 9 staff and community members of the SI participated in the food tasting event. Though there is an indigenous garden on the SI premises, these nine

Figure 4.1: Respondents serving *soutslaai* salsa and *smoortjie*

Figure 4.2: Layout of the food tasting venue

respondents were not actively engaged in that garden, and for that reason were not biased. Each respondent signed a consent form as ethically required. The questionnaire administered contained both closed and open-ended questions. It consisted of three parts: first, demographic questions and questions concerning prior knowledge of the vegetables were asked; second, a sensory score sheet consisting a 5-point hedonic scale ranging from 1 = 'extremely unacceptable' to 5 = 'extremely acceptable' to measure acceptability; and lastly, a 6-score food action ration scale (FACT) ranging from 1 = 'I will never eat' to 6 = 'I would eat it every day' was used to measure consumption intent. Another 5-point scale ranging from 1 = 'definitely would not' to 5 = 'definitely would' to measure purchasing intent for these Cape wild vegetables (Barrett *et al.*, 2010; Heinrichs and Ellison, 2016; Matenge *et al.*, 2012). Respondents were asked to circle the number that, for them, best described how they felt about each vegetable in terms colour, smell, texture, taste, and overall acceptance of the recipes. Due to the small sample size, all the responses were analysed individually using excel and similar responses were grouped into themes and further broken down into sub-themes.

4.2.5 Analysis

Frequency tables were generated for the demographic information about respondents, to show attitudes towards each recipe, consumption intent and purchasing intent. Spearman's rho analysis was used to investigate correlations between the overall acceptance of dune spinach and *soutslaai*. Additionally, correlations between the overall acceptance of the Cape wild vegetables by consumption intent and purchasing intent were made. Shapiro-Wilk's test, histograms, normal Q-Q plots, skewness and kurtosis were used to test the assumption of normality. When the assumption test for normality and symmetrical distribution was violated, the exact sign test was used. The sign test was carried out to determine whether there was a population median difference between the paired observations, i.e. between the recipes of each vegetable (Fong *et al.*, 2012). In other words, the sign test was used to compare the positive and negative differences in the acceptability scores between each recipe for each vegetable. The exact p value was used because the sample size was less than 25. The Welch test was used to compare the overall acceptance means of the Cape wild vegetables between genders and the Mann-Whitney U test was used to compare overall acceptance means of the Cape wild vegetables between students and working professionals (Bergmann *et al.*, 2000). Statistical significance was set at $p < 0.05$ with a confidence level of 95 %. It must be stated that since purposive sampling was used, the results of the study cannot be generalised and are specific to the population in this study. Data was analysed using SPSS for Windows, version 25 (SPSS Inc., Chicago, Illinois).

4.2.5.1 Missing Data Analysis and Reliability

There are different types of missing data. Within the context of this study, the Little's Missing Completely at Random Test (MCAR) was carried out on the variables with missing survey data that was not clearly marked as 'no response'. The MCAR test was done to check and replace values determined to be missing completely at random. For example, if questions or sections of the questionnaire were accidentally skipped rather than purposefully. To generate predicted values for the missing data, the Expectation Maximization Algorithm was used (Musil *et al.*, 2008). The MCAR test was done on the data measuring the consumer response to the dune spinach and the *soutslaai*. The goal of this test was to increase the correlation between the items measuring consumer acceptability of the dune spinach and *soutslaai* particularly since the sample size was small (n = 24). Because the MCAR test on the dune spinach data generated a Little's MCAR test: $\chi^2(12) = 16,159$, $p = 0.184$. Since the result was not statistically significant, it was concluded that the data was missing completely at random. The MCAR test on the *soutslaai* data generated a Little's MCAR test: $\chi^2(11) = 13.314$, $p = 0.273$. The result was not statistically significant. Therefore, we do not reject the null hypothesis which states that the data is missing completely at random. This result allowed for the replacement of the missing values with predicted values to allow us to work on a complete data set. This is more powerful than analysing an incomplete data set especially when the sample size is small.

The Cronbach's alpha reliability test was used to validate the reliability and internal consistency of each dataset used before analysis. A good Cronbach's Alpha level is required to be 0.70 and higher because this indicates a high degree of reliability between the data measured for each variable, i.e. the 'acceptance of the dune spinach salsa' or 'acceptance of dune spinach *smoortjie*' (Tavakol and Dennick, 2011). Basic statistics results, histograms, normal Q-Q plots are in the Appendix D and E[1]. For this study, variables will refer to 'acceptance of the dune spinach salsa', 'acceptance of dune spinach *smoortjie*', 'acceptance of *soutslaai* salsa' and the 'acceptance

[1]Tables and figures referenced with a letter-number caption (e.g. Figure D.1) are located in the Appendix.

of *soutslaai smoortjie*', 'dune spinach acceptance score' and '*soutslaai* acceptance score'.

4.3 Results

4.3.1 Demographic Information and Prior Knowledge

A total of 24 respondents participated in the food tasting event. Of these respondents, 16 (67 %) were female and 8 (33 %) were male as shown in Table 4.1. At least 11 (46 %) of the respondents were working professionals while 13 (58 %) were students. Most of the respondents 21 (88 %) had spent the first 18 years of their life in South Africa, while only 3 (12 %) had lived outside of the country for the first 18 years of their life. Thirteen (54 %) of the respondents where affiliated with Stellenbosch University, while 9 (38 %) where affiliated with the SI. When respondents were asked if they had any knowledge of dune spinach and *soutslaai* before the day of the survey, the majority, 15 (62 %) respondents had no knowledge of either one as depicted in Table 4.2. Of the five respondents who indicated that they knew the plants from their institutions, four of them said it was through the SI that they had this knowledge. These four also indicated that they had eaten either vegetable or both before the study. The presence of an indigenous garden on the SI premises does not bias these respondents' as consumption was not ongoing and the vegetables were not presented as eaten before. The remaining respondent had heard about *soutslaai* in class. Two respondents (8 %) stated that their source of information regarding these species was by word of mouth, with one having been introduced to both species by a local indigenous person. One respondent (4 %) reported to have encountered *soutslaai* growing by the beach in Gansbaai, Western Cape. Most of the respondents, 20 (83 %), had neither eaten dune spinach nor *soutslaai* before the event.

Table 4.1: Demographic information of dune spinach and *soutslaai*

Demography	Respondents	Category	Frequency	Valid Percent
Gender	24	Female	16	67 %
		Male	8	33 %
Age	24	18-24	1	4 %
		25-35	14	58 %
		>36	9	38 %
Occupation	24	Student	13	54 %
		Working Professional	11	46 %
Homeland	24	South Africa	21	88 %
		Other Country	3	12 %
Affiliated Institution	22	Stellenbosch University	13	54 %
		Sustainability Institute	9	38 %

Table 4.2: Knowledge frequency of dune spinach and *soutslaai*

Prior Knowledge	Respondents	Category	Frequency	Valid Percent
Knowledge of dune spinach and *soutslaai* as Cape wild vegetables	24	Dune spinach	1	4 %
		Soutslaai	4	17 %
		Both	4	17 %
		Neither	15	62 %
Source of knowledge	8	Institution	5	22 %
		Word of mouth	2	8 %
		Nature	1	4 %
Eaten dune spinach or *soutslaai* before	24	Dune spinach	1	4 %
		Both	3	13 %
		Neither	20	83 %
Where respondents had eaten dune spinach or *soutslaai* before	4	Institution	4	17 %
Perception of Wild Leafy Vegetables	41 responses	Positive Perceptions	20	83%
		Negative Perception	18	75 %
		No Perceptions	3	13 %

4.3.2 Perceptions of Indigenous Vegetables

Of the 24 respondents, 20 (83 %) of them had positive responses regarding their perception of wild leafy vegetables, 18 respondents (75 %) had negative perceptions while 3 respondents (13 %) had neither negative nor positive perceptions about indigenous vegetables. In Tables 4.3 and 4.4 a list of the positive and negative perceptions is broken down into themes and sub-themes based on the respondent's responses.

4.3.3 Respondent's Overall Acceptability of the Recipes

A Cronbach's alpha analysis revealed that the respondent's 'acceptance of the dune spinach salsa' and 'acceptance of dune spinach *smoortjie*' were 0.789 and 0.855, respectively, indicating the items for each variable had an adequate level of inter-item reliability. The alpha levels generated for the respondent's 'acceptance of *soutslaai* salsa' and the 'acceptance of *soutslaai smoortjie*' were 0.85 and 0.757 respectively indicating an adequate level of inter-item reliability among the items used to measure each factor.

4.3.3.1 Data Characteristics

The Shapiro-Wilk's test for normality was violated for the overall acceptance scores for the dune spinach salsa ($p = 0.017$), dune spinach *smoortjie* ($p < 0.001$), *soutslaai* salsa ($p = 0.013$) and *soutslaai smoortjie* ($p = 0.001$). A visual inspection of the histogram and normal Q-Q plots in Figure D.1 and Figure D.2 and the skewness and kurtosis shown in Table D.1 showed that data differed significantly from normality.

Table 4.3: Respondents' positive perceptions of wild leafy vegetables

Theme	Sub-Themes	Respondent Response	Frequency	Valid Percent
Sustainable	Sustainability	Environmentally friendly and sustainable Sustainability	13	52 %
	Eco-friendly	Environmentally friendly Diversity		
	Economical	Good for economic purposes Cheap Affordable		
	Nutrition	Healthy/organic food Very good for health and style of eating food. Nutritious		
Heritage	Local	local Its indigenous, Local people get to grow it. Nearby Vegetables that come from a specific area	7	28 %
	Culture	I will, cook it at my own home It makes me think of home or anything one can be proud of Cultural Heritage		
Taste	Delicious	I enjoy conventional vegetables very much. I prefer most vegetables over fruit. Delicious	3	12 %

4.3.3.2 Sign Test for Dune Spinach Salsa and *Smoortjie*

An exact sign test illustrated in Figure D.3 was used to compare the positive and negative differences in the acceptability scores given for each of the dune spinach recipes separately. The cooked dune spinach recipe, 'dune spinach smoortjie', elicited a statistically significant median increase in acceptability compared to the raw dune spinach recipe, 'dune spinach salsa', exact $p = 0.035$. Of the 24 respondents, 12 respondents found the dune spinach *smoortjie* more acceptable compared to the dune spinach salsa. In addition, 3 respondents had a 'negative difference' therefore they did not find the cooked version of the dune spinach more acceptable than the raw one. Lastly, for 9 respondents, the style of cooking had no effect on acceptability of the dune spinach. The frequencies of 24 respondents attitudes towards dune spinach texture are illustrated in (Figure 4.3).Based on the responses, 53 % of the respondents liked the texture of the dune spinach salsa and *smoortjie*, while only 17 % disliked the texture of the dune spinach salsa and *smoortjie*. Twenty-four percent of the respondents gave neutral comments about the texture of the dune spinach. The specific attitudes towards the texture of both dune spinach recipes can be found in Table C.1 (Appendix C).

Table 4.4: Respondents' negative perceptions of wild leafy vegetables

Theme	Code	Respondent Response	Frequency	Valid Percent
Distaste	Distaste	Inedible I guess it will be green, leafy and with an acrid taste. Never tasted it before Not tasty Do not love wild stuff Maybe not too tasty	6	21 %
Unsustainable	Accessibility	Accessibility, Not accessible Difficult to find	6	21 %
	Non-economical	Yield Amount Ability to meet the demand as it can't be supplied by other area		
	Ecological threat	Potential over-harvesting		
Perception	Belief	That it is "indigenous" makes me doubt that I will like it Negative perception i.e. viewed as less appealing Wild	7	25 %
	Knowledge	Don't know how it tastes Don't know if I can eat it Too little knowledge Unknown – not familiar with		
Unsafe	Pathogens	Potential pathogens located on vegetables I am wary of new foods	2	8 %

4.3.3.3 Sign Test for *SoutSlaai* Salsa and *Smoortjie*

The assumption of normality and the symmetrical distribution of the difference between the related groups *soutslaai* salsa and *soutslaai smoortjie* was violated. An exact sign test illustrated in Figure D.4, revealed that the *soutslaai* salsa did not generate a statistically significant median increase in acceptability compared to the *soutslaai smoortjie*, exact $p = 0.092$. Of the 24 respondents, 10 respondents found the *sout slaai smoortjie*, more acceptable compared to the *soutslaai* salsa. Three respondents had a 'negative difference' therefore did not find the *soutslaai smoortjie* more acceptable than the *soutslaai* salsa. Lastly, for 11 respondents, the style of cooking had no effect on how acceptable they found the *soutslaai*. The frequencies of 24 respondents' attitude towards the texture of the *soutslaai* salsa and *smoortjie* are demonstrated in Figure 4.4. Based on the responses, 71 % of the respondents liked the texture of the *soutslaai* salsa and *smoortjie*, while only 11 % disliked the texture of the *soutslaai* salsa and *smoortjie*. A tabulation of the specific attitudes towards the texture of both *soutslaai* recipes can be found in Figure C.2.

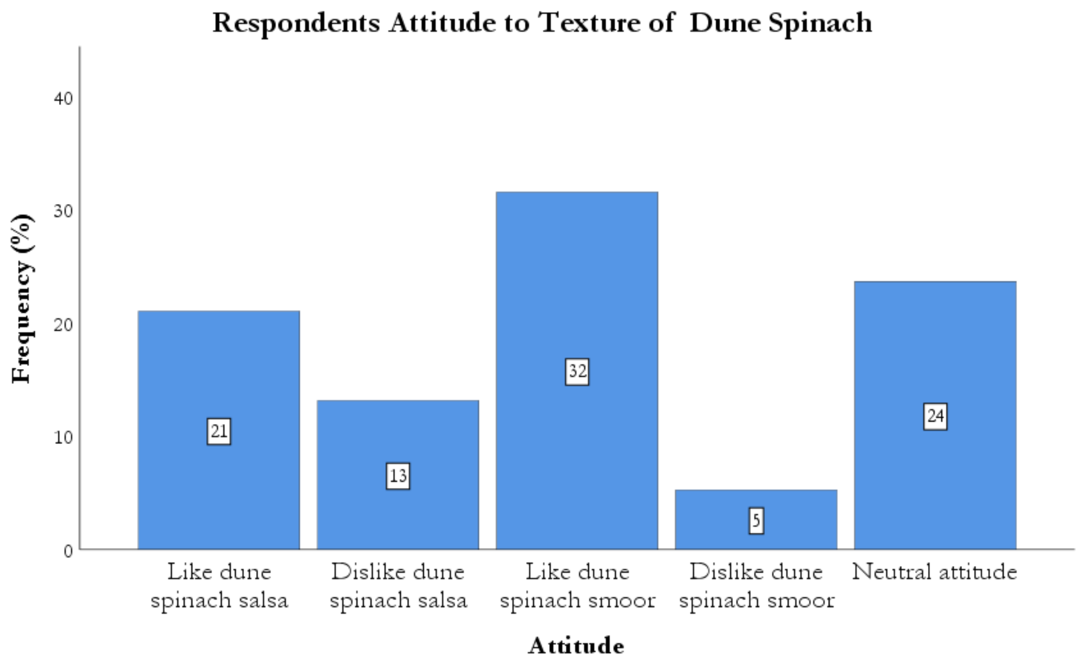

Figure 4.3: Respondents attitudes towards the texture of the dune spinach based on responses

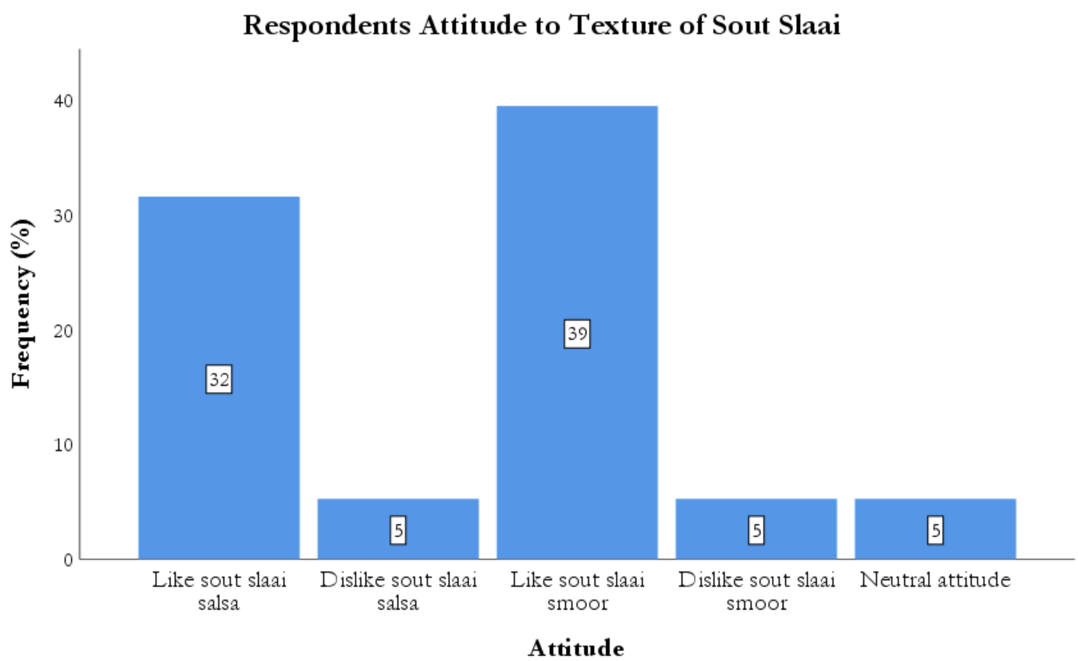

Figure 4.4: Respondents attitudes towards the texture of the *soutslaai* based on responses

4.3.4 Acceptability of Dune Spinach and *soutslaai* as Indigenous Cape Wild Vegetables

Cronbach's Alpha analysis yielded alpha reliability levels of 0.559 and 0.717 respectively for 'dune spinach acceptance score' and '*soutslaai* acceptance score'. The low alpha level for the items measuring 'dune spinach acceptance score' demonstrated an inadequate level of inter-

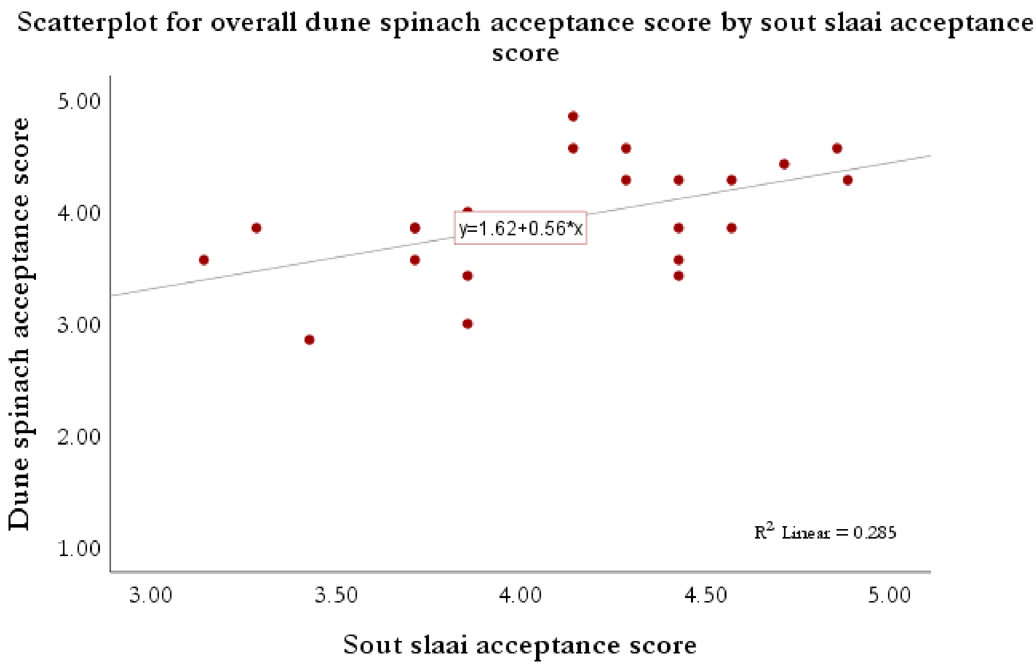

Figure 4.5: Scatterplot illustrating the correlation between the dune spinach acceptance score and the *soutslaai* acceptance score

item reliability. In addition, further analysis found that deleting any of the items would not have significantly increased the alpha level. On the other hand, the alpha level for the items measuring the '*soutslaai* acceptance score' showed an adequate level of inter-item reliability. Preliminary analysis, in the form of a scatterplot shown in Figure 4.5, was generated as a visual demonstration of the relationship between the overall acceptance of dune spinach and *soutslaai*. The analysis showed the relationship to be monotonic, while showing a general trend for the data to move upwards in a positive direction. Furthermore, Spearman's rho correlation analysis tabulated in Table E.1, showed a statistically significant moderately strong positive correlation between the 'dune spinach acceptance score' and the '*soutslaai* acceptance score', $r(23) = 0.514$, $p = 0.01$.

4.3.5 Overall Acceptance Mean Scores of Two Indigenous Cape Wild Vegetables by Gender

Welch's unequal variance t-test was conducted to compare the population means for overall acceptance score of both Cape wild vegetables between the significantly different samples sizes of men (6) and women (18). There was no significant difference between the acceptability scores for men and women, $t(1) = 1.253$, $p = 0.223$. There were no differences in how acceptable the men and women found both the indigenous vegetables.

4.3.6 Overall Acceptability Mean Scores of Two Indigenous Cape Wild Vegetables by Occupation

A Mann-Whitney U test conducted to determine whether there were differences in overall acceptance score for both Cape wild vegetables between students and working professionals did not have similarly shaped distributions as assessed by visual inspection of Figure D.5. There was no statistically significant difference in overall acceptance scores between students and working professionals, $U = 63.5$, exact $p = 0.649$.

4.3.7 Overall Acceptance of Cape Wild Vegetables, Consumption Intent and Purchasing Intention

4.3.7.1 Acceptance of Indigenous Vegetables Versus Consumption Intent

A visual inspection of the scatterplot in Figure 4.6 demonstrated a monotonic but non-linear relationship between overall acceptance of Cape wild vegetables and consumption intent. Spearman's rho correlation coefficient shown in Table E.2 revealed there was no association between consumption intent and overall acceptance of the two Cape wild vegetables, $r(23) = 0.362$, $p = 0.082 > 0.05$. The frequencies of respondents' intended consumption are illustrated in Figure 4.7.

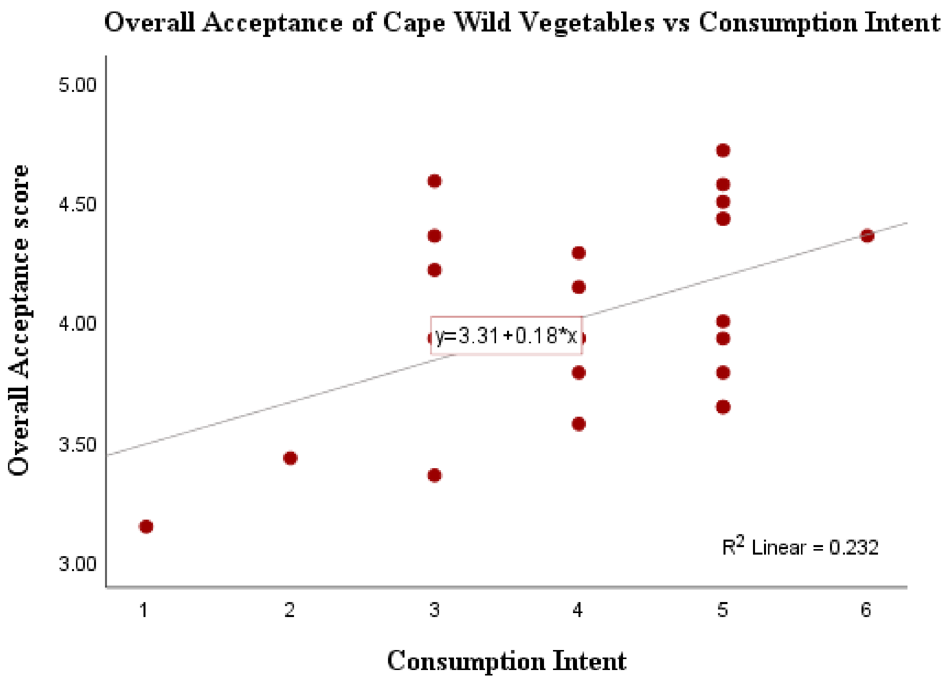

Figure 4.6: Scatterplot showing correlation between overall acceptance and consumption intent

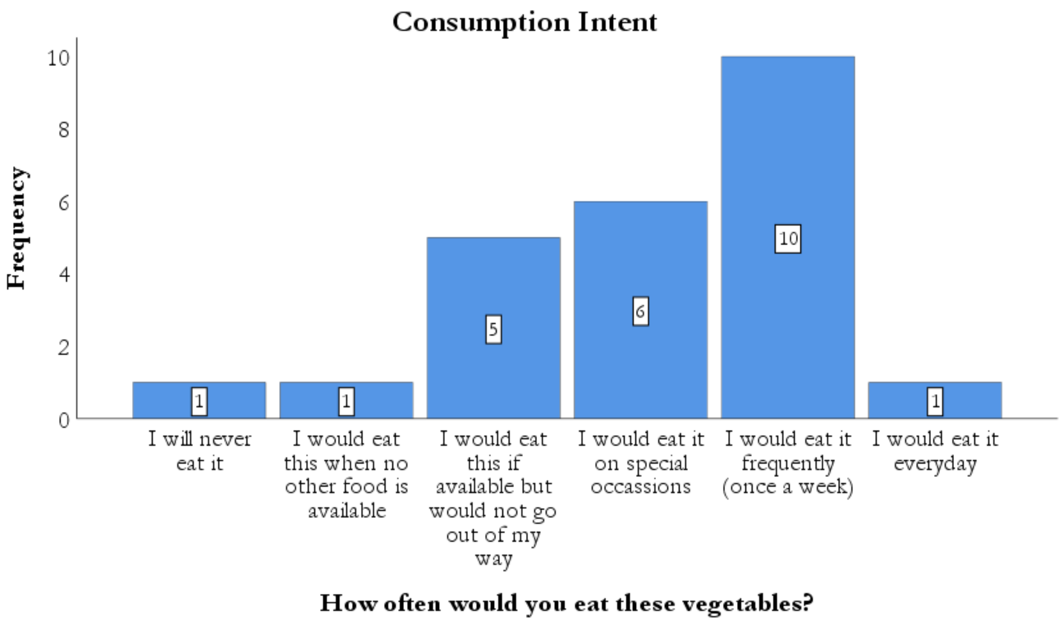

Figure 4.7: Frequency of respondents intended consumption of dune spinach (*T. decumbens*) and *soutslaai* (*M. crystallinum*

4.3.7.2 Acceptance of Cape Wild Vegetables vs Purchasing Intention

A visual inspection of the scatterplot in Figure 4.8 showed there was a monotonic but non-linear relationship between overall acceptance of the Cape wild vegetables and purchasing intent. There was a positive upward trend from lower left to upper right and the correlation coefficient generated was significant as shown in Table E.3, $r(23) = 0.698$, $p < 0.001$. Therefore, there is a strong positive association between respondent's purchasing intention and the overall acceptance of the two Cape wild vegetables. A visual representation of respondent's purchasing intent is depicted in Figure 4.9. Spearman's rank-order correlation coefficient displayed in Table E.4 was generated to show any relationship between the respondent's consumption intent and purchasing intention for the two indigenous vegetables was statistically significant. Therefore, there was a strong monotonic but non-linear relationship between the respondent's consumption intent and purchasing intention for the two Cape wild vegetables, $r(23) = 0.601$, $p = 0.002$. The scatterplot in Figure 4.10 demonstrates the monotonic relationship between consumption intent and purchasing intention for the vegetables.

The main themes, sub-themes and direct quotations that emerged when respondents were asked (open-ended question) under what circumstances they would buy the Cape wild vegetables are listed in Figure 4.11. The main themes that emerged were frequency of vegetable purchase, respondent's economic situation surrounding, the presence of a local market that sells these vegetables. In addition, purchases of these vegetables would depend on information available on them and health reasons Figure 4.11 illustrates the frequencies of respondents reasons for purchasing Cape wild vegetables by theme.

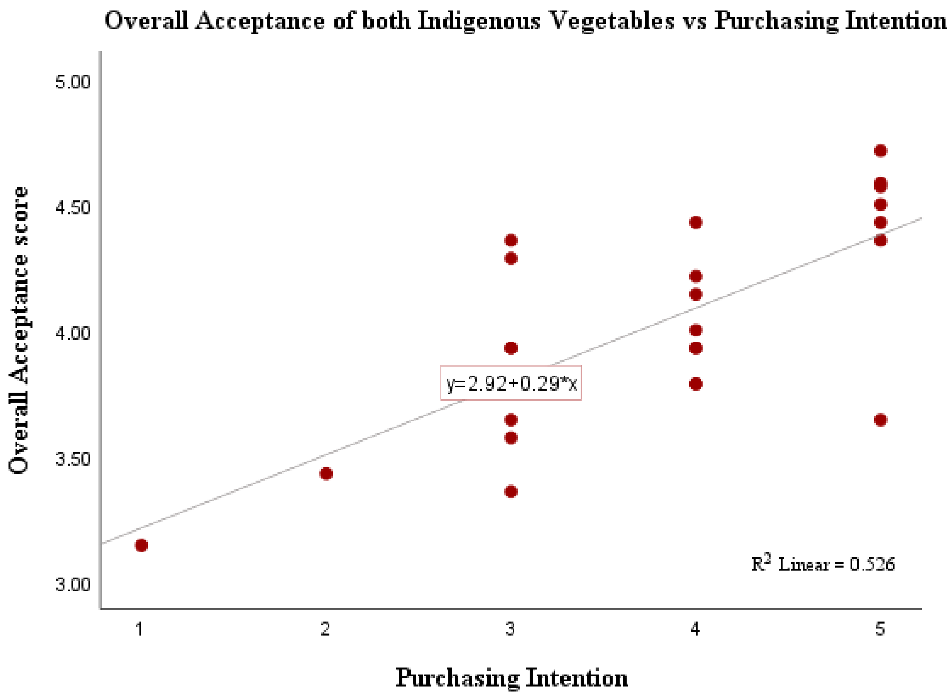

Figure 4.8: Scatterplot showing correlation between overall acceptance and purchasing intent

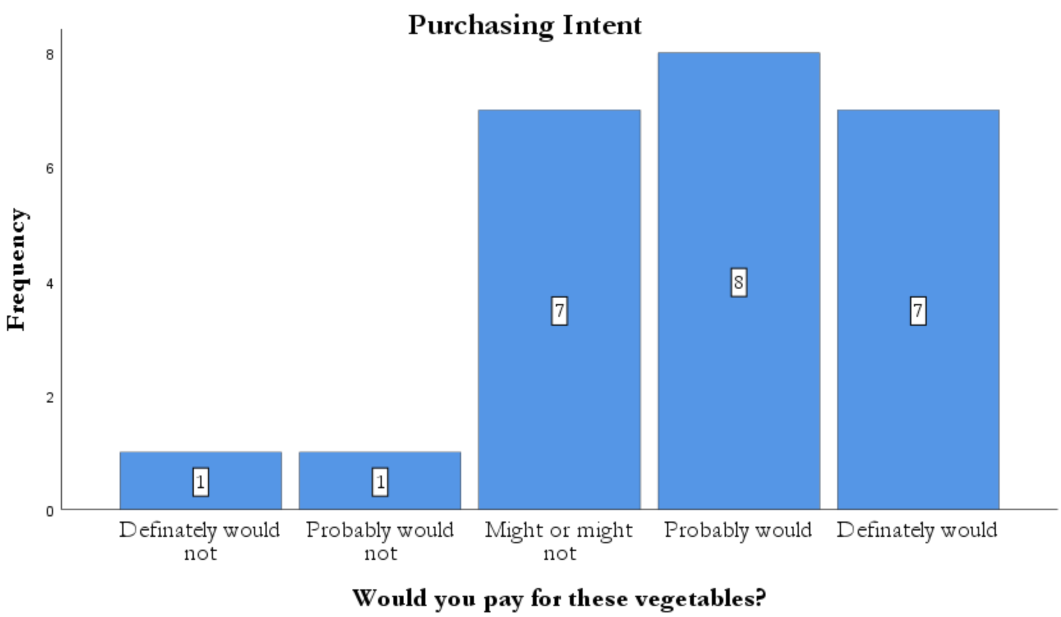

Figure 4.9: Frequency of respondent's purchasing intention pay for Cape wild vegetables

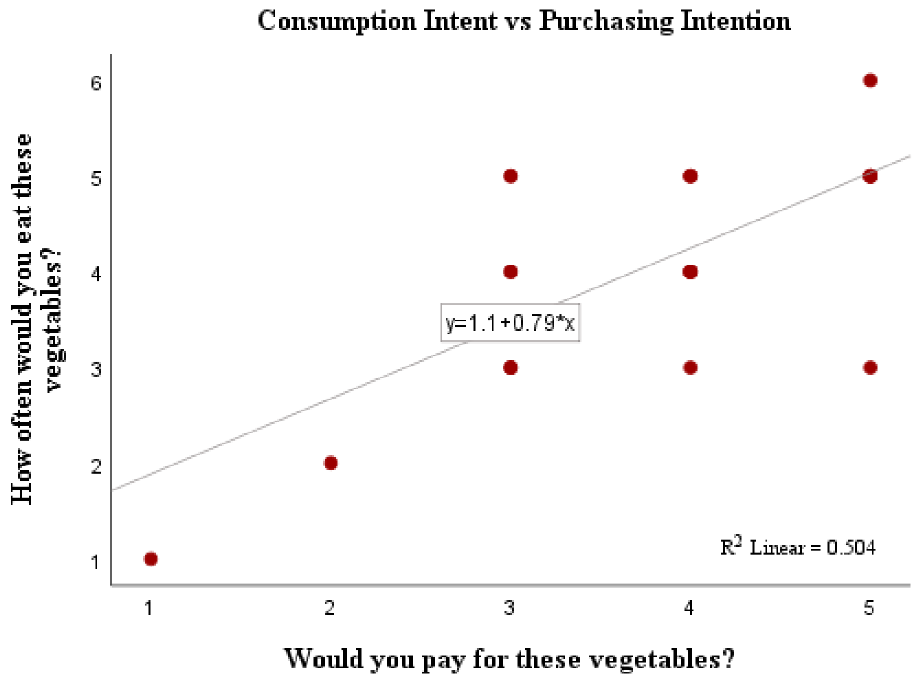

Figure 4.10: Scatterplot showing correlation between consumption intent and purchasing intention

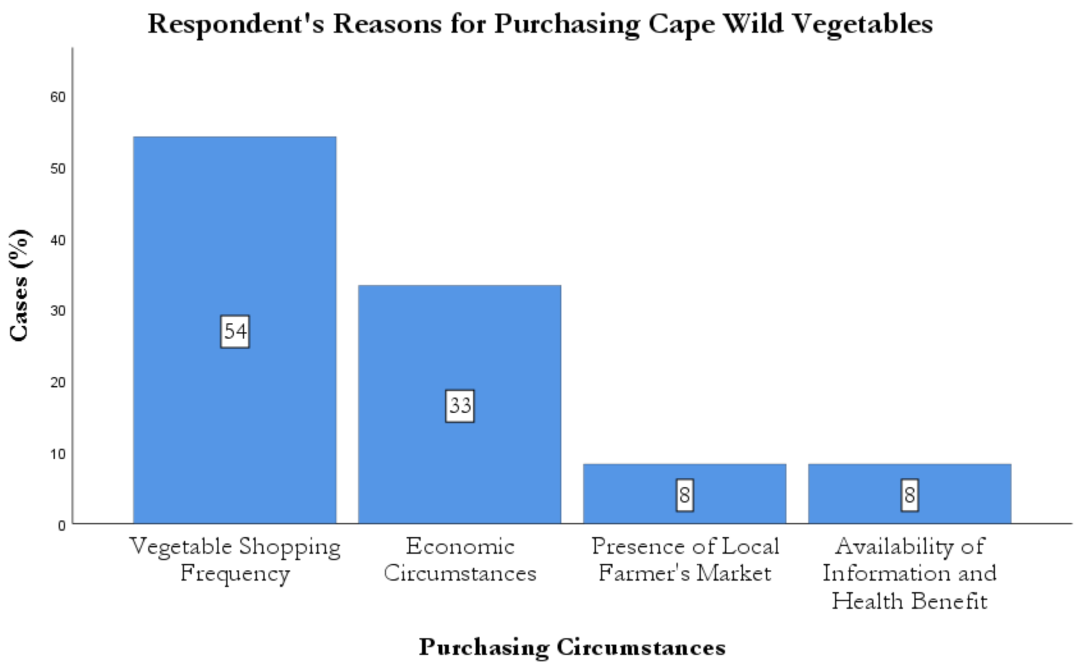

Figure 4.11: Circumstances surrounding respondents' purchase of Cape wild vegetables

Table 4.5: Respondents' responses to the question of what circumstances would prompt them to purchase either of these two vegetables

Theme	Sub-theme	Respondent Response
Frequency	Anytime	These vegetables taste so good, I would buy it anytime. I really enjoyed it! Normal everyday circumstances Whenever I go shopping Normal circumstances on the shelves I would buy it as part of my weekly grocery shopping! It is very delicious.
	Occasional	I would consider doing that to eat it every now and then. I cook once a week with my house mates. For a braai I would purchase the soutslaai to make a side salad or to add it to the tomato and onion relish. At home I would also encourage my family to purchase this. This is an easy substitute for many salad ingredients. If presented at local food markets I would purchase both vegetables on a frequent basis would buy them at least once a week
	Special Occasion	For special occasions and just to add onto other meals I fast intermittently several times a year. It is a partial fast, so that is when I would easily buy and prepare these vegetables. Especially the soutslaai. If specifically asked to cook a bredie containing these vegetables For Heritage Day recipes
Economics	Affordable	If it is cheaper than other vegetables and readily available When it is affordable and attainable. Also, economically, these would by much cheaper to purchase so yes, I would buy these to make a meal.
	Available	If they were available at the market or in the shop I would buy them If it is cheaper than other vegetables and readily available When it is affordable and attainable. If they are available to buy or grow, I would consider doing that to eat it every now and then.
	Nothing Else	If there is nothing else available or if you pair it with the right combination of ingredients like the onion relish with meat. Will not go out of my way to make it If there is nothing else to eat
Market	Local	If presented at local food markets I would purchase both vegetables on a frequent basis. I would love to experiment with these two vegetables in my own kitchen At local farmer markets with as little processing and packaging as possible
Other	Information	If a 'how to'instruction or information section came with the plant
	Health	I like a healthy diet and as such would buy them at least once a week

4.4 Discussion

A convenience sample of 24 respondents participated in a survey that assessed their acceptance of two edible fynbos plant species indigenous to the CFR: *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*). At a food tasting event organised at the Sustainability Institute in Lynedoch, respondents were questioned regarding any prior knowledge of the two species after which their acceptance of the two leafy vegetables was explored.

Over half the respondents (62 %) had no prior knowledge about either dune spinach or *soutslaai* and 83 %had never eaten either vegetable before as shown in Table 4.2. This was not surprising and corroborates literature referring to knowledge regarding wild foods being preserved with marginalised indigenous communities in the Western Cape (De Vynck *et al.*, 2016*a*,*b*; Singels *et al.*, 2016). Respondents had both positive and negative perceptions about indigenous vegetables. Of the respondents that gave positive perceptions about indigenous vegetables, sustainability was the most important positive perception that was recorded. This was closely followed by heritage and taste. Thirteen respondents (52 %) believed that indigenous vegetables are environmentally friendly, biodiverse, affordable, good for economic purposes, nutritious and healthy. Hoeven *et al.* (2013) reported nutrition, health and economic benefits as important positive perceptions of a group of primary school going children's parents in the North West province of South Africa. In this study indigenous vegetables were perceived as being high in vitamins that can boost immunity and help prevent disease. Another study conducted in the North-West province of South Africa investigating consumer beliefs of indigenous and traditional foods listed nutrition and health as two of the most important benefits of indigenous foods. Indigenous foods were described as natural and unrefined and consequently beneficial in preventing disease as well as providing healing in the case of illness (Matenge *et al.*, 2012). However, the lack of knowledge and information regarding nutritional status and quality during processing or preservation of these foods was also described as one the the barriers to increasing acceptability and preference for them as healthier choices. Other studies have shown similar results and research investigating nutritional quality is on the rise (Dweba and Mearns, 2011; Bvenura, 2014; Singels *et al.*, 2016).

Heritage was the second most important theme that 7 (28 %) of the respondents mentioned. Under heritage were the sub-themes; local meaning indigenous or originating from a particular area and culture. The occurrence of the sub-themes of culture and heritage in the context of indigenous food demonstrate the influence that identity and upbringing have on perceptions of food. A study by Wright *et al.* (2001) linking cultural influences and food taste preferences, suggests understanding heritage and culture is a good start to understanding food taste preferences. Matenge *et al.* (2012) found that culture and the tradition of passing on knowledge regarding indigenous vegetable uses gave value to their consumption.

Promotion of indigenous vegetables in societies that are increasingly multi-cultural may involve presenting them in a way society can identify with. Under the current study, respondents mentioned that not only can the indigenous nature of local vegetables benefit indigenous people but also enable the respondents to cook these vegetables in their own homes, remind them of family and make them feel proud of their heritage. Lastly, 3 respondents (12 %) stated that indigenous vegetables are delicious.

Table 4.4 illustrates the prominent negative perceptions, also called barriers, respondents listed were the taste of indigenous vegetables, a general belief that they will not like the vegetables and the fact that they are unsustainable. Thirteen respondents in total (46 %), stated dislike of taste, wariness and lack of knowledge as their negative perceptions of indigenous vegetables. Respondents perceived indigenous vegetables as unappealing, inedible and expected the taste to be acrid and distasteful. Additionally, the fact that indigenous vegetables are wild foods by nature was not an attractive or appealing feature. This perception of distaste, added to the lack of knowledge on these vegetables made respondents cautious of them. The perception of taste as being either positive or negative has been seen in other studies (Wright *et al.*, 2001; Penafiel *et al.*, 2016). Furthermore, diversity in cooking methods or lack thereof have also been found to influence perception of taste. Therefore, it is suggested that the promotion of indigenous vegetables that are unknown should include recipes on how to prepare them.
The second most important negative perception was that indigenous vegetables are unsustainable. Six respondents (21 %) stated that indigenous vegetables are not accessible and difficult to find. Furthermore, they perceived to be non-economical because of the low yield and thus would not be able to meet demand because it would be difficult to supply them to other areas. Lastly, the potential for over-harvesting was a major concern making indigenous vegetables an ecological threat. Two respondents (8 %) were wary of indigenous vegetables and stated concern over their safety of due to potential pathogens that may be located on them. Bvenura and Afolayan (2015) has reported the false perception of fear of poisoning due to consuming the wrong indigenous vegetable even though there have been no reports of poisoning except regarding wild mushrooms. Food safety, culture or heritage, nutrition and health benefits are all themes that other studies have stated as drivers for indigenous food consumption (Matenge *et al.*, 2012), though in this study, the frequencies of these themes were low due to the small sample size.

With respect to the sensory section of the survey, the recipes of each vegetable were compared within the vegetable in question. That is, dune spinach was not compared to *soutslaai* at the recipe level. The cooked dune spinach recipe, 'dune spinach *smoortjie*', elicited a statistically significant median increase in acceptability compared to the raw dune spinach recipe, 'dune spinach salsa', as depicted in Figure D.3. Twelve of the respondents found the dune spinach *smoortjie* more acceptable than the dune spinach salsa. Three respondents with the 'negative difference' did not find the cooked version more acceptable than the raw one. For nine respondents, the style of cooking had no effect on how acceptable they found the dune spinach.
On the contrary, Figure D.4 shows that the *soutslaai* salsa did not generate a statistically significant median increase in acceptability compared to the *soutslaai smoortjie*. Even so, 10 respondents found the *soutslaai smoortjie* more acceptable in comparison to the *soutslaai* salsa. Three respondents had a 'negative difference' meaning they did not find the *soutslaai smoortjie* more acceptable than the *soutslaai* salsa. For 11 respondents, the style of cooking had no effect

on how acceptable they found the *soutslaai*. Based on these results, cooking the dune spinach slightly increased its acceptability to the respondents. This suggests that the acceptability of the vegetables was tied to the texture of the vegetables. Furthermore, an analysis of respondent's attitudes towards the texture of the dune spinach and *soutslaai* in Appendix C may give some insight into the reasons why the style of cooking had no effect on the 9 out of 24 respondents for dune spinach and 12 out of 24 respondents for *soutslaai*.

Texture plays a significant role in consumers' consumption decision making (Matenge *et al.*, 2012). Based on the frequency of attitudes towards texture illustrated in Figure 4.3 and Figure 4.4, respondents generally liked both recipes. However, the dune spinach salsa was least liked and the texture was most bothersome or unique between the two. Nonetheless, a tabulation of respondents direct quotations in Appendix C show that while some felt the texture of the leaf did not change much between its raw and cooked forms and the ingredients of the salsa did not compliment the dune spinach, the tomato flavour made an incredible difference in the taste of the *smoortjies* by adding a different flavour. One respondent mentioned that the *smoortjie* looked more familiar to them and reminded them of home. It was suggested that the *smoortjie* could be served with rice. Those who liked the *smoortjie* liked the tomato and chilly flavour and preferred the juicy yet crunchy texture the *soutslaai* maintained. The *soutslaai* was described as having a mushroom-like texture. One respondent said the *smoortjie* was less sour compared to the salsa and another said it had sweeter taste.
Within this study context, a neutral response referred to responses that did not explicitly state whether the salsa or *smoortjie* was liked or disliked and statements that gave very general comments about the recipes. Respondents who had a neutral response to the texture stated that they found the texture a bit strange and where slightly bothered by the rough, strong, salty and sharp taste of the salsa. However, the taste marginally improved in the cooked *smoortjie*. Therefore, it may be safe to say that the neutral comments leaned more towards favouring the *smoortjie*. Some respondents stated that the ingredients in the salsa did not go well with the dune spinach. Those that disliked the dune spinach *smoortjie* stated that the other ingredients did not fit the vegetable well and that the raw dune spinach left a dry, bitter and sour after-taste.

Results from the survey also indicated a moderately strong positive correlation between the 'overall acceptance of dune spinach vegetable' and the 'overall acceptance of *soutslaai* vegetable'. Therefore, people who found the dune spinach vegetable acceptable, also found the *soutslaai* vegetable acceptable. Gender had no effect on how acceptable the two indigenous vegetables were, and therefore, within the context of this study, these two Cape wild vegetables were found to be acceptable to both men and women (Delacre *et al.*, 2017). This result agrees with Matenge *et al.* (2012) whose study showed that there was no positive association between gender and acceptability. However, Vorster (2007) found that men perceived indigenous vegetables as food for women and children thus preferring to eat meat. Likewise, occupation had no bearing on how acceptable the indigenous vegetables were.

There was no association between consumption intent and overall acceptance of the two indigenous vegetables. In other words, a higher acceptability score of the Cape wild vegetables did not mean that the respondents were willing to consume them again. This result was not surprising because while only one out of 24 respondents said they would eat these vegetables every day, 10 said they would eat the vegetables at least once a week, 6 respondents said they would only eat them on special occasions like Heritage Day, and 5 respondents said they would not go out of their way to eat the vegetables as shown in Figure 4.7. Other literature has shown that if respondents generally find a food acceptable, they will want to consume them (Scholtz and Bosman, 2005; Matenge *et al.*, 2012). Within this study, the lack of a significant correlation between respondents' overall acceptance of the two vegetables and intended future consumption may be attributed to the small sample size. It may be that investigating a larger group of respondents may give a different result. This response may also suggest that respondents may have overstated their acceptance of the vegetables or, that even though people may like how something new tastes that does not mean they would want to adopt it into their diets. However it has been found that providing information on the health benefits of vegetables increases consumption and attitudes towards them (Jemmott *et al.*, 2011).

On the other hand, there was a strong positive association between respondents' purchasing intention and the overall acceptance of the two indigenous vegetables. Therefore, we conclude that respondents who found both dune spinach and *soutslaai* acceptable were also willing to pay for them. Figure 4.9 shows that fifteen respondents said that they probably and definitely would not purchase these vegetables, while only 7 respondents said they might or might not buy the vegetables. Only two respondents said that they probably or definitely would not buy the vegetables. This dynamic may be as a result of the ease of access to a market by urban dwellers (Senyolo *et al.*, 2014).
There was also a strong positive but monotonic relationship between respondents' intent to consume the vegetables again and their purchasing intention. Therefore, respondents that intended to consume these vegetables were also willing to buy them. This means if either consumption intent or purchasing intention increases so will the other value increase. However, it may also mean if either consumption intent or purchasing intention increase, the other will decrease. Similar results were observed in a study by Dahlia *et al.* (2012) that showed that as indigenous vegetable consumption increased so did the magnitude of purchase. A study by Ayanwale *et al.* (2016) in Nigeria indicated that with an increase in indigenous vegetable preference and an awareness of nutritional value can lead to a state where consumers will purchase the vegetables regardless the price because of the value attributed to them.

When respondents were asked what circumstances would be needed for them to purchase the vegetables the most important reason given for consumption was the frequency with which the respondents would do their general shopping of vegetables (Figure 4.11, Table 4.5). Frequency of shopping outweighed price, the availability of both vegetables at a local farmers market, information and health as reasons to motivate consumption of dune spinach and *soutslaai*. This may indicate that the presence of dune spinach and *soutslaai* on the shelves of retail outlets might increase consumption as potential consumers would have the opportunity to purchase them (Gido *et al.*, 2017). Additionally, more frequent visits to the market source would encourage the the purchasing of more commodities per transaction which would include vegetables since they are perishable (Dahlia *et al.*, 2012). Economic circumstances surrounding the purchase of the indigenous vegetables emerged as the second most important theme. Availability of the vegetables, price and for some, the lack of any other vegetable to consume would determine whether respondents would purchase these wild vegetables. Additionally, respondents said they would purchase these vegetables if there was a local farmer's market at which they would be sold. Finally, access to adequate information regarding the vegetables and health reasons were regarded as important considerations when purchasing these vegetables.

4.5 Conclusion

To start with, no generalisations are made from the results of this study as the sample size was not a representation of the Western Cape population. Additionally, because SPSS Statistics has not yet implemented a way to handle the ties (responses that were neither positive nor negative) that were generated with a sign test, the validity of the conclusion can be questioned. The data could have been transformed to use the more powerful Wilcoxon signed-rank test but this would have altered the ranking of the results and consequently caused issues with interpretation. All the same, within the study context, we determined that the cooked versions of the dune spinach and *soutslaai* were better liked than the raw versions. Based on these results, it would be recommended that the marketing of these two Cape wild leafy vegetables should include information about them and suggest recipes, particularly sautéed versions of the vegetables.

In second place, there was a positive relationship between the overall acceptance and potential consumers' purchasing intention but no relationship between the overall acceptance of the indigenous vegetables and consumption intent. The most important reason to purchase these vegetables that emerged was the frequency of shopping and the desire to eat them. This may indicate that the presence of these two vegetables on the shelves of food stores may encourage consumption. Furthermore, availability and price emerged as the second most important factors that would affect the purchasing of these two wild vegetables.
To conclude, information regarding level of sustainability, nutrient content or health benefits and suggested preparation methods on packaging may aid with promoting their adoption into diets. Further studies are needed at a larger scale to investigate perceptions and potential adoption of Cape wild vegetables.

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Chapter 5

Conclusion

The CFR is a biodiversity hotspot that has been well studied for its ecology and floral diversity. As one of the six major plant kingdoms, its rich genetic and biological biodiversity is celebrated in spite of many of the species being endemic. Literature available on the agronomic performance of the edible species in the semi-arid regions of the CFR are not extensive. The cultivation and adoption of indigenous leafy vegetables have a significant role is addressing food and nutrition security in the Western Cape.

An agronomic and social study were conducted to investigate the agronomic performance of *T. decumbens* (dune spinach) and *M. crystallinum* (*soutslaai*). In addition, an indigenous food tasting event was conducted to explore potential consumer acceptance and adoption of the two species as alternative food and nutrition sources. Chapters 1 and 2 introduce the reader to the two edible fynbos species by providing some definitions, a description of the species and background information.

Chapter 3 investigated the agronomic performance of dune spinach and *soutslaai*. The statistical results of the study indicated that increases in water quantities of both dune spinach and *soutslaai* grown in coastal sandy soils (dune soil) did not significantly optimise growth and biomass accumulation. Dune spinach and *soutslaai* utilized less than 50 % of the water required for plant growth within the study context. On the contrary, significant differences in agronomic performance were observed amongst the soil treatments and control. Soil analysis before and after both trials showed increases in selected soil nutrients due to the growth of dune spinach and *soutslaai*.

Chapter 4 explored the levels of acceptance of a convenience sample of 24 respondents to dune spinach and *soutslaai* recipes. Respondents expressed both negative and positive perceptions about indigenous vegetables in general. A statistical analysis of the responses showed that they generally preferred the cooked version of the dune spinach and *soutslaai*. Responses regarding consumption intent did not positively correlate with their overall acceptance of the vegetables. On the other hand, respondents were very willing to purchase dune spinach and *soutslaai* if they were available.

While the results of the agronomic and consumer perception study are not generalizable due to the small sample size, a conservative extrapolation of the study suggests that *T. decumbens* and *M. crystallinum* are well suited as alternative food and agronomic resources in the Western Cape region. Firstly, their halophytic nature makes them sustainable crops for growers affected by climate change effects. They are tolerant of very high and low temperatures, increasing soil salinity and particularly drought as both species utilised less than half of the water that was required for plant growth within the study. Physiological, morphological and molecular adaptations to biotic and abiotic stresses have significant value in the face of climate variability.

Halophyte's economic use of water during growth can significantly decrease fresh water utilization in crop farming. Naturally, the high tolerance of dune spinach and *soutslaai* to drought conditions makes them alternative water-efficient plants appropriate for agricultural use in the Western Cape. Futhermore, both species have the potential to produce abundant biomass while utilising marginal soils and irrigation water. There is also potential for high yield with the addition of extra soil nutrients. However, resource-poor growers would not be disadvantaged in producing sufficient yield in soils of low fertility because of the potential for biomass accumulation to increase under soils of high salt concentration. Notably, these edible fynbos species have the potential to remediate saline and sodic soils for agrarian uses. Agricultural lands that have been rendered unsuitable for conventional crops can be reclaimed by these species making them more suitable for non-halophytic species. Additionally, they can provide a source of food and income for economically resource-poor farmers owning marginal lands. The present study also showed the potential for dune spinach and *soutslaai* to increase certain soil nutrients or make them more available in the soil for plant use. Lastly, these species possess antimicrobial properties that potentially aid in making them resilient towards pests, fungal infections and disease. This is beneficial for economically resource-poor growers who would not need to invest too much capital in plant protection options.

Secondly, dune spinach and *soutslaai* have a potential to break into mainstream market as alternative and nutritious leafy vegetables. With the right recipes they are acceptable vegetables that are already used in selected restaurants in the Western Cape. Provided that they are affordable and marketed with information regarding origin, sustainability and nutrition, consumers would be willing to purchase and aid their adoption into modern diets. What is more is their potential medicinal and health benefits due to their antimicrobial and antioxidant qualities and ability to accumulate micronutrients. These edible fynbos species that can be added to urban vegetable gardens easily and thereby addressing the dual issues of aesthetics and nutrition. *Soutslaai* in particular has potential as a "super food" because it synthesizes and accumulates a myriad of metabolites needed for human nutrition that are presently acquired through commercial supplement tablets.
T. decumbens (dune spinach) and *M. crystallinum* are climate-concious Cape wild vegetables that can address food and nutrition insecurity, climate variability, water scarcity and mitigate the loss of arable land give agricultural value to marginal range lands.

5.1 Limitations

It must be noted that these species are wild and as far as was known at the time of the study, had not been investigated for agronomic performance under tunnel conditions in the Western Cape. The ground work done by Ms. Loubie Rusch layed a foundation as to which species would be easiest to propagate. Both species are yet to be tested inland, with the exception of the Sustainability Institute. Nonetheless, there was little academic literature that has been generated on the performance of dune spinach and *soutslaai* as food crops in the field. Regarding growth potential, the size of the plant pots and nutrient depletion limited further growth. Furthermore, in determining soil nutrient increases when comparing analysed soil nutrient parameters before and after, the water quality and leachate were not analysed and taken into account. Finally, the small sample size of the consumer survey deters from generalising the results as the respondents did not represent the Western Cape population.

5.2 Recommendations

Gaps in academic literature regarding Cape wild vegetables exist in many areas. Firstly,there is need for extensive field trials that can investigate the effects of additional nutrients, population densities and intercropping, marginal water and drought stress on agronomic performance and taste of dune spinach and *soutslaai*. Other areas include nutritional analysis, carbon sequestration potential, germination studies and seed biology, food processing and adoption and acceptability studies. Secondly, there is need to explore the extent to which dune spinach and *soutslaai* can amend marginal agrarian lands as the results of this study suggested that both dune spinach and *soutslaai* can increase soil nitrogen and reduce soil salinity. Thirdly, further studies with sample sizes that represent the Western Cape population are needed to investigate utilization, perceptions and potential adoption of wild edible species indigenous to the area. Furthermore, there is need for studies to be conducted over longer periods of time that provide evidence for the efficacy of using agroecological practices. There is need to document detailed information, particularly regarding yield and disease resistance, on alternative agricultural practices that are comparable to conventional farming systems.

Lastly, research that is community based and takes into account agroecological designs will help expand on literature showing how indigenous resources and sustainable, regenerative practices can mitigate environmental, nutritional and socio-economical challenges.

Appendices

Appendix A

Statistical Analysis

A.1 Dune Spinach: Irrigation Treatment Growth Parameters, Biomass Accumulation and Physiological Parameters

Normality assumption was violated if more than one treatment group's population deviated from the normality assumption ($p < 0.05$). Data is presented as mean ± standard deviation unless otherwise stated. Outliers were retained because they were neither measured nor entered incorrectly. Means are only reported for data sets with no outliers because their presence or absence did not affect the result but affected the normality assumption of two out of four treatment groups. If data was normally distributed, outliers were retained.

The data for dune spinach height had no outliers and was approximately distributed as assessed by a boxplot and Shapiro-Wilk's test ($p > 0.05$). There was homogeneity of variance for height as assessed by Levene's test ($p = 0.327$). The mean height of the dune spinach was higher for the irrigation treatments at 25 % ($M = 0.29$, $SD = 3.82$), 50 % ($M = 0.25$, $SD = 5.03$) and 80 % ($M = 0.26$, $SD = 7.61$) was higher when compared to the control ($M = 0.23$, $SD = 4.62$) though the irrigation treatment means for height were not statistically significant, $F(3, 36) = 2.613$, $p = 0.066$. There were two outliers in the data measuring the number of dune spinach runners as assessed by the inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The outliers were kept in the analysis as they did not result from a measurement or data entry error. The normality assumption was violated for one treatment level assessed the Shapiro-Wilk's test ($p < 0.05$). There was homogeneity of variances as assessed by Levene's test, ($p = 0.141$). The one-way ANOVA was carried out for all number of runners because it is still a robust test to deviations from normality and a Type 1 error especially when the treatment sizes were equal (Maxwell, 2003). The mean number of runners for the irrigation treatments at 25 % ($M = 4.40$, $SD = 2.413$), 50 % ($M = 3.70$, $SD = 1.337$) and 80 % ($M = 3.10$, $SD = 2.025$) was higher when compared to the control ($M = 2.80$, $SD = 1.814$). However, there were no statistically significant differences in number of runners between the different irrigation treatments, $F(3, 36) = 1.333$, $p = 0.279$). The data measuring dune spinach leaf area index (LAI) had one outlier and was normally distributed as assessed by the boxplot and Shapiro-Wilk test ($p > 0.05$) respectively. The homogeneity of variances assumption for the leaf area index was violated as assessed by Levene's test ($p = 0.018$). A one-way ANOVA showed the population means for LAI were not statistically significantly different for the different irrigation treatments, Welch's $F(3, 19.427) = 0.811$, $p = 0.503$.

The data measuring fresh mass (FM) whole plant biomass had one outlier as assessed by a boxplot and was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p = 0.002$). A one-way ANOVA showed the population means for FM root biomass were not statistically significantly different for the varying treatments, Welch's $F(2, 19.474) = 2.516$, $p = 0.088$. The data measuring the FM shoot biomass had three outliers and the normality assumption for two out of four treatment groups was violated as assessed by the Shapiro-Wilk test ($p < 0.05$). A Kruskal-Wallis H test showed the distributions of the FM shoot biomass populations were not similar for all water treatments, as assessed by a visual inspection of a boxplot. The FM shoot biomass mean ranks were statistically significantly different between the treatments, Kruskal Wallis $\chi^2(3) = 10.793$, $p = 0.013$. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. The post hoc analysis revealed statistically significant differences between the 25 % water treatment (mean rank = 7.14) and the 50 % water treatment (mean rank = 10.26) ($p = 0.014$). The data measuring FM root biomass had two outliers as assessed by a boxplot and was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p = 0.01$). An ANOVA showed the population means for FM root biomass were not statistically significantly different for the varying treatments, Welch's $F(3, 19.429) = 0.911$, $p = 0.454$. Contrary to our hypothesis, the population means for FM root biomass were equal. The data measuring FM leaf biomass had two outliers and normality assumption for two out of four treatment groups was violated as assessed by the Shapiro-Wilk test ($p < 0.05$). Distributions of the FM shoot biomass populations were not similar for all water treatments, as assessed by a visual inspection of a boxplot. A Kruskal-Wallis H test showed the FM leaf biomass mean ranks were statistically significantly different between the treatments, Kruskal Wallis $\chi^2(3) = 11.542$, $p = 0.009$. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. The post hoc analysis revealed statistically significant differences between the 25 % water treatment (mean rank = 4.67) and the 50 % water treatment (mean rank = 6.91) ($p = 0.019$) as well as the 25 % treatment and the 80 % treatment level (mean rank = 7.27) ($p = 0.025$). No other group differences where statistically significant. The data measuring dry mass (DM) leaf biomass had three outliers as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.671$). The population means for DM leaf biomass were statistically significantly different for the varying water treatments, $F(3, 36) = 8.365$, $p = 0.005$. Tukey post hoc analysis revealed that the increase in DM leaf biomass from the control ($M = 0.775$, $SD = 0.246$) to the 25 % water treatment ($M = 1.214$, $SD = 0.372$, $p = 011$), the 50 % treatment ($M = 1.414$, $SD = 0.316$, $p < 0.001$) and the 80 % treatment ($M = 1.223$, $SD = 0.227$, $p = 0.009$) were statistically significant. No other group differences where statistically significant. The data measuring DM root to shoot ratio had no outliers as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p = 0.039$). The population means for DM root to shoot ratio were not statistically significantly different for the varying water treatments, Welch's $F(3, 19.182) = 2.094$, $p = 0.135$. Contrary to our hypothesis, the population means for DM root to shoot ratio were equal.

The data measuring stomatal conductance (SC) had no outliers and was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p < 0.001$). A one-way ANOVA showed the population means for dune spinach SC were statistically significantly different for the different water treatments, Welch's $F(3, 18.151) = 44.873$, $p < 0.001$. Games-Howell post hoc analysis revealed that SC significantly increased from the control ($M = 0.54$, $SD = 39.44$) to 50 % ($M = 1.78$, $SD = 578.61$, $p < 0.001$). There was also a significant decrease in stomatal conductance from the control to the 25 % irrigation treatment ($M = 0.43$, $SD = 77.23$, $p = 0.004$) and the 80 % treatment ($M = 0.40$, $SD = 27.57$, $p < 0.001$) but no significant difference between any other groups. The data measuring chlorophyll content index (CCI) had no outliers and was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). There was homogeneity of variances as assessed by the Levene's test for homogeneity of variance ($p = 0.147$). The population means for dune spinach CCI were not statistically significantly different for the different water treatments, $F(3, 36) = 0.74$, $p = 0.535$.

A.2 *Sout Slaai:* Irrigation Treatment Growth Parameters, Biomass Accumulation and Physiological Parameters

The data measuring plant size had one outlier and the normality assumption and homogeneity of variances was violated as assessed by the Shapiro-Wilk's ($p < 0.05$) and Levene's test ($p = 0.829$) respectively. An ANOVA showed that the mean *sout slaai* plant size increased from the treatment receiving no water ($M = 11.03$, $SD = 1.68$) to the 25 % treatment ($M = 11.82$, $SD = 1.83$) then decreased at the 50 % treatment ($M = 11.33$, $SD = 2.25$) and decreased again at the 80 % treatment ($M = 11.93$, $SD = 2.30$) through the differences between the population means were not statistically significant, $F(3, 36) = 0.433$, $p = 0.73$. The normality assumption was severely violated as assessed by the Shapiro-Wilk test ($p < 0.05$). A Kruskal-Wallis H test showed the distributions of the leaf pair populations were not similar for all the treatments, as assessed by a visual inspection of a boxplot. The mean ranks of the leaf pairs were not statistically significantly different between the treatments, $\chi^2(3) = 8.374$, $p = 0.39$. The data measuring LAI had no outliers and was approximately normally distributed as assessed by the Shapiro-Wilk test ($p > 0.05$). There was homogeneity of variances as assessed by a visual inspection of the boxplot, and Levene's test ($p = 0.333$). The mean leaf area index was highest at the 25 % irrigation treatment level ($M = 13.66$, $SD = 3.76$) and lowest at the 50 % level ($M = 10.71$, $SD = 2.18$) though there was no statistically significant difference between the population means, $F(3, 36) = 1.817$, $p = 0.162$.

The data measuring FM whole plant biomass had one outlier as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.659$). An ANOVA showed the population means for FM whole plant biomass were not statistically significantly different for the varying water treatments, $F(3, 36) = 1.748$, $p = 0.175$. Contrary to our hypothesis, the population means for FM whole plant biomass are equal. The data measuring FM shoot biomass had three outliers as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.331$). An ANOVA showed the population means for FM shoot biomass were not statistically significantly different for the varying water treatments, $F(3, 36) = 2.165$, $p = 0.109$. Contrary to our hypothesis, the population means for FM shoot biomass are equal. The data measuring FM root biomass had one outlier and the normality assumption for two out of four treatment groups was violated as assessed by the Shapiro-Wilk test ($p < 0.05$). A Kruskal-Wallis H test showed distributions of the leaf pair populations were not similar for all water treatments, as assessed by a visual inspection of a boxplot. The medians of the FM root biomass were not statistically significantly different between the treatments, Kruskal Wallis $\chi^2(3) = 5.863$, $p = 0.118$. The data measuring FM shoot biomass had no outliers as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.807$). An ANOVA showed the population means for FM shoot biomass were statistically significantly different for the varying water treatments, $F(3, 36) = 3.033$, $p = 0.042$. Tukey's post hoc analysis revealed that the decrease in FM leaf biomass from the 25 % water treatment ($M = 14.48$, $SD = 0.431$) to the 50 % water treatment ($M = 9.39$, $SD = 4.53$, $p = 0.039$). The data measuring DM leaf biomass had no outliers as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.815$). An ANOVA showed the population means for DM leaf biomass were not statistically significantly different for the varying water treatments, $F(3, 36) = 1.905$, $p = 0.146$. The data measuring DM root to shoot ratio had no outliers as assessed by a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$) and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.597$). An ANOVA showed the population means for DM root to shoot ratio were not statistically significantly different for the varying water treatments, $F(3, 36) = 0.723$, $p = 0.545$.

The data measuring SC had two outliers; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p = 0.01$). An ANOVA showed the population means for *sout slaai* SC were statistically significantly different for the varying water treatments, Welch's $F(3, 18.42) = 47.42$, $p < 0.001$. Games-Howell post hoc analysis revealed that stomatal conductance significantly increased from the control ($M = 0.72$, $SD = 68.88$) to the 25 % irrigation treatment ($M = 1.04$, $SD = 206.16$, $p = 0.003$). There was a significant decrease in stomatal conductance from the control to the 50 % irrigation treatment ($M = 0.29$, $SD = 159.04$, $p < 0.001$) and the 80 % treatment ($M = 0.35$, $SD = 124.19$, $p < 0.001$). There was a significant difference between the 25 % treatment and the 50 % and 80 % irrigation treatment but no significant difference between any other groups. The data measuring CCI had no outliers as assessed by a boxplot. The data was also approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p < 0.001$). An ANOVA showed the population means for CCI were statistically significantly different for the varying water treatments, Welch's $F(3, 18.186) = 3.614$, $p = 0.033$. Games-Howell post hoc analysis revealed that there was a statistically significant increase in the CCI between the 25 % irrigation treatment ($M = 24.2$, $SD = 16.76$) and the 80 % irrigation treatment ($M = 30.01$, $SD = 4.60$, $p = 0.02$). There was no significant difference between any other groups.

A.3 Dune Spinach: Soil Treatment Growth Parameters, Biomass Accumulation and Physiological Parameters

The assumption for normality was violated for more than one of the treatment groups as assessed in the Shapiro-Wilk test ($p > 0.05$). A Kruskal-Wallis test showed distributions of the dune spinach height were not similar for all soil treatments, as assessed by the visual inspection of a boxplot. The mean ranks for dune spinach height were statistically significantly different between the soil treatments, $\chi^2(3) = 20.84$,Â $p < 0.001$. Subsequently, pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. This post hoc analysis revealed statistically significant differences in mean ranks between the control (0.24 m) and SI soil (0.43 m) ($p = 0.004$), and the Welgevallen Experimental Farm (WEF) soil (0.19 m) and the Sustainability Institute (SI) soil ($p < 0.001$) but not between the WEF soil and control. The data measuring dune spinach runners had no outliers and was approximately normally distributed as assessed by the Shapiro-Wilk test ($p > 0.05$). Homogeneity of variances was violated as assessed by a visual inspection of the boxplot, and Levene's test ($p = 0.019$). An ANOVA revealed differences between the population means were not statistically significant, Welch's $F(2, 15.499) = 2.917$, $p = 0.082$. Data measuring LAI had two outliers as assessed by a boxplot; data was approximately normally distributed for each treatment as assessed by the Shapiro-Wilk test ($p > 0.05$); and there was homogeneity of variances as assessed by Levene's test of homogeneity of variances ($p = 0.183$). The ANOVA showed population means for LAI were statistically significantly different for the different soil types, $F(2, 27) = 135.07$, $p < 0.001$. Tukey post hoc analysis revealed that the increase in LAI from the control ($M = 2.59$, $SD = 0.48$) to the SI soil ($M = 7.73$, $SD = 0.94$) was statistically significant ($p < 0.001$) as well as for the control and the WEF soil ($M = 7.64$, $SD = 0.90$, $p < 0.001$). No other group differences where statistically significant.

The data measuring FM whole plant biomass had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for FM whole plant biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 13.311) = 31.72$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that all the group differences were statistically significant. The data measuring FM shoot biomass had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for FM shoot biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 13.468) = 44.974$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that all the group differences were statistically significant ($p < 0.001$). The data measuring FM root biomass had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for FM root biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 13.468) = 18.718$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in FM root biomass from the control ($M = 3.39$, $SD = 0.686$) to the SI soil treatment ($M = 14.61$, $SD = 6.141$) was statistically significant, $p = 0.001$. The decrease from the control to the WEF soil ($M = 2.59$, $SD = 0.981$) was significantly different (p < 0.001) but no other groups differed significantly. The data measuring FM leaf biomass had one outlier as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for FM leaf biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 13.495) = 74.721$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that all the group differences were statistically significant ($p < 0.001$). The data measuring DM leaf biomass had one outlier as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for DM leaf biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 15.733) = 30.084$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that all the group differences were statistically significant. The data measuring DM root to shoot ratio had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p = 0.015$). AN ANOVA showed the population means for DM root to shoot ratio were statistically significantly different for the varying soil treatments, Welch's $F(2, 15.091) = 61.479$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in DM root to shoot ratio from the control ($M = 0.80$, $SD = 0.176$) to the WEF soil treatment ($M = 0.33$, $SD = 0.066$) was statistically significant, $p < 0.001$. There was also a significant difference between the SI soil treatment ($M = 0.81$, $SD = 0.149$) and the WEF soil treatment ($p < 0.001$). There was no significant difference between the control and the SI soil treatment.

The data measuring SC had one outlier as assessed by a boxplot. The data was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p < 0.001$). An ANOVA showed the population means for SC were statistically significantly different for the varying treatments, Welch's $F(2, 14.262) = 21.293$, $p < 0.001$. Games-Howell post hoc analysis revealed that there was a statistically significant increase in the SC between the control ($M = 388.79$, $SD = 35.16$) and the SI soil treatment ($M = 1044.94$, $SD = 409.24$, $p = 0.02$) and a statistically significant decrease in the SC between the control and the WEF soil treatment ($M = 282.62$, $SD = 72.35$, $p = 0.03$). There was a statistically significant difference in the SC between the SI soil and WEF soil treatments, ($p = 0.01$). The data measuring CCI had no outliers as assessed by a boxplot. The data was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p = 0.03$). An ANOVA showed the population means for CCI were statistically significantly different for the varying treatments, Welch's $F(2, 13.09) = 185.69$, $p < 0.001$. Games-Howell post hoc analysis revealed that there was a statistically significant increase in the CCI between the control ($M = 5.66$, $SD = 1.31$) and the SI soil treatment ($M = 40.98$, $SD = 5.86$, $p < 0.001$) and a statistically significant decrease in the CCI between the control and the WEF soil treatment ($M = 20.32$, $SD = 5.86$, $p < 0.001$). There was a statistically significant difference in the CCI between the SI soil and WEF soil treatments, ($p < 0.001$).

A.4 *Sout Slaai:* Soil Treatment Growth Parameters, Biomass Accumulation and Physiological Parameters

The data measuring plant size had no outliers and was approximately normally distributed as assessed by the Shapiro-Wilk test ($p > 0.05$). The homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p < 0.001$). An ANOVA showed the population means for *sout slaai* size were statistically significantly different for the different soil types, Welch's $F(2, 16.008) = 55.634$, $p < 0.001$. Games-Howell post hoc analysis revealed that plant size significantly increased from the control ($M = 9.05$, $SD = 1.11$) to the SI soil ($M = 19.45$, $SD = 4.64$, $p < 0.001$) and the WEF soil ($M = 14.33$, $SD = 1.45$, $p < 0.001$). There was also a statistically significant difference in plant size between the SI soil and WEF soil treatments ($p = 0.018$). The normality assumption for data measuring number of leaf pairs was severely violated as assessed by the Shapiro-Wilk test ($p < 0.05$). A Kruskal-Wallis H test showed distributions of the leaf pair populations were not similar for all soil treatments, as assessed by a visual inspection of a boxplot. The mean ranks of the leaf pairs were not statistically significantly different between the treatments, $\chi^2(2) = 2.548$, $p = 0.28$. The data measuring LAI had no outliers and was approximately normally distributed as assessed by the Shapiro-Wilk test ($p > 0.05$). The homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p < 0.001$). An ANOVA showed the population means for *sout slaai* LAI were statistically significantly different for the different soil types, Welch's $F(2, 14.47) = 38.176$, $p < 0.001$. Games-Howell post hoc analysis revealed that plant size significantly increased from the control ($M = 12.76$, $SD = 1.56$) to the SI soil ($M = 27.5$, $SD = 6.57$, $p < 0.001$) and the WEF soil ($M = 20.31$, $SD = 3.45$, $p < 0.001$). There was a statistically significant difference in plant size between the SI soil and WEF soil treatments ($p = 0.022$).

The data measuring FM whole plant had one outlier as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for FM whole plant were statistically significantly different for the varying soil treatments, Welch's $F(2, 14.561) = 24.933$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in FM whole plant biomass from the control ($M = 8.60$, $SD = 3.16$) to the SI soil treatment ($M = 41.14$, $SD = 23.77$, $p = 0.005$) and between the control and the WEF soil treatment ($M = 21.74$, $SD = 6.09$, $p < 0.001$) was statistically significant. There was no significant difference between the SI soil treatment and the WEF soil treatment. The data measuring the FM shoot biomass had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). AN ANOVA showed the population means for FM shoot biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 13.939) = 29.001$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in FM shoot biomass from the control ($M = 7.66$, $SD = 2.49$) to the SI soil treatment ($M = 35.92$, $SD = 20.18$, $p = 0.004$) and between the control and the WEF soil treatment ($M = 21.04$, $SD = 5.86$, $p < 0.001$) was statistically significant. There was no significant difference between the SI soil treatment and the WEF soil treatment. The data measuring FM leaf biomass had one outlier as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p = 0.006$). An ANOVA showed the population means for FM leaf biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 15.456) = 31.181$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in FM leaf biomass from the control ($M = 5.90$, $SD = 2.74$) to the SI soil treatment ($M = 28.52$, $SD = 17.0$, $p = 0.006$) and between the SI soil and the WEF soil treatment ($M = 17.2$, $SD = 4.09$, $p < 0.001$) was statistically significant. There was no significant difference between the SI and the WEF soil treatment. The data measuring DM leaf biomass had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p < 0.001$). An ANOVA showed the population means for DM leaf biomass were statistically significantly different for the varying soil treatments, Welch's $F(2, 14.49) = 31.472$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in DM leaf biomass from the control ($M = 0.50$, $SD = 0.18$) to the SI soil treatment ($M = 2.66$, $SD = 1.62$, $p = 0.006$) and between the SI soil and the WEF soil treatment ($M = 1.38$, $SD = 0.34$, $p < 0.001$) was statistically significant. There was no significant difference between the SI and the WEF soil treatment. The data measuring DM root to shoot ratio had no outliers as assessed by a visual inspection of a boxplot; was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$); and the homogeneity of variances was violated as assessed by Levene's test of homogeneity of variances ($p = 0.042$). An ANOVA showed the population means for DM root to shoot ratio were statistically significantly different for the varying soil treatments, Welch's $F(2, 13.878) = 26.278$, $p < 0.001$. Further analysis using Games-Howell post hoc analysis revealed that the increase in DM root to shoot ratio from the control ($M = 0.26$, $SD = 0.13$) to the WEF soil treatment ($M = 0.11$, $SD = 0.039$, $p = 0.01$) and between the SI soil ($M = 0.39$, $SD = 0.13$, $p < 0.001$) and the WEF soil treatment was statistically significant. There was no significant difference between the control and the SI soil treatment.

The data measuring SC had no outliers as assessed by a boxplot. The data was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p < 0.001$). An ANOVA showed the population means for SC were statistically significantly different for the varying treatments, Welch's $F(2, 13.57) = 20.04$, $p < 0.001$. Games-Howell post hoc analysis revealed that there was a statistically significant increase in the SC between the control ($M = 131.35$, $SD = 53.73$) and the SI soil treatment ($M = 283.35$, $SD = 147.06$, $p = 0.26$) and a statistically significant increase in the SC between the control and the WEF soil treatment ($M = 893.11$, $SD = 408.8$, $p = 0.001$). There was a statistically significant difference in the SC between the SI soil and WEF soil treatments, ($p = 0.002$).

The data measuring CCI had no outliers as assessed by a boxplot. The data was approximately normally distributed among all treatment groups as assessed by the Shapiro-Wilk test ($p > 0.05$). The assumption of homogeneity of variances was violated as assessed by the Levene's test for homogeneity of variance ($p = 0.013$). An ANOVA showed the population means for CCI were statistically significantly different for the varying treatments, Welch's $F(2, 15.4) = 56.17$, $p < 0.001$. Games-Howell post hoc analysis revealed that there was a statistically significant increase in the CCI between the control ($M = 25.2$, $SD = 3.13$) and the SI soil treatment ($M = 49.27$, $SD = 7.67$, $p < 0.001$) and a statistically significant increase in the CCI between the control and the WEF soil treatment ($M = 41.79$, $SD = 6.65$, $p < 0.001$). There was no significant difference between any other groups.

Appendix B

Recipes

Table B.1: Recipes of dune spinach and *soutslaai* salsa and *smoortjie*

Dune spinach/*Soutslaai salsa*	
1 chopped onion	**1/2-1 chilli depending on heat preference**
1/2 chopped green pepper	**2 cm peeled, finely chopped fresh ginger**
Juice of one lemon	**1-2 cups chopped dune spinach/*sout slaai***
Rind of 1/4 lemon	**1/4 tsp salt**
Mix the finely chopped onions, green peppers, ginger, some green chilli and lemon rind and set aside to stand overnight in some lemon juice and salt. Add the salsa mix and some olive oil to the chopped dune spinach and *sout slaai* 15 minutes before serving.	
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Dune spinach / *Soutslaai smoortjie*	
1 chopped onion	**1/2 to 1 can whole tomato**
1/2 chopped green pepper	**2 cm peeled, finely chopped fresh ginger**
Rind of 1/4 lemon	**1/2 chilli depending on heat preference**
Olive oil for sautéing	**1/4 tsp salt**
Reduce tomato in a saucepan by half to thicken and intensify flavour. SautÃ© finely chopped chilli, onion, green pepper, ginger and lemon rind until onion is translucent. Add reduced tomato and stir through for a minute. In a separate pan, add 1 tbsp of oil and stir fry the dune spinach or *soutslaai* for 3 minutes or until just wilted. Stir the wilted greens into the tomato mix and adjust salt as needed.	
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Appendix C

Respondents' Attitudes

Table C.1: Respondents' attitudes towards the texture of the dune spinach salsa and *smoortjie*

Theme	Responses
Likes (Raw Texture)	Really liked raw recipe. The texture was quite tough but still good. I prefer it cold. Texture of the leaf doesn't change whether cooked or not which is nice. The addition of other ingredients makes it nicer and healthier. Very good prepared with the pasta flour. I love the dune spinach raw and cooked. Both the *soutslaai* is juicy, less sour and has a gentler texture in both cases. the smoortjie options were very delicious. I've now had four portions. For the raw dune spinach, the ginger combined with the spinach was extremely tasty Loved the taste of the combinations. Texture on its own is a little bit rough to eat.
Dislikes (Raw Texture)	I would blame mostly the other ingredients used in the raw recipe, especially the onions. Do not prefer the texture. The taste isn't great but if I can get used to them I'll certainly get used to the taste. When you chew the dune spinach there is just a dry, sour, bitter husk left in my mouth. The raw one gave me a headache.
Likes (Cooked Texture)	The warm was also very nice. The texture was less rough but loved them both. Want more. The cooked one is really nice. Taste was incredible, especially the cooked one. Texture of the leaf doesn't change whether cooked or not which is nice. The addition of other ingredients makes it nicer and healthier. Taste much better cooked and flavored with tomato than raw. Also looks more familiar to me. It tastes and looks like a *smoortjie* which I associate with home and comfort home. Would be great with rice. Going back for seconds. Cooked tastes much better, more variance in flavor and tomato makes a massive difference. There is a lot more flavor with the second tasting. The fusion of spice along with the tomato compliments the dune spinach. Very good prepared with the pasta flour. I love the dune spinach raw and cooked. Loved the taste of the combinations. Texture on its own is a little bit rough to eat. Tastes much better when cooked. The cooked recipe was fantastic.
Dislikes (Cooked Texture)	The texture of the leaf bothered me more than the warm dish. Do not prefer the texture. I did not like the texture of the cooked product.

	The taste isn't great but if I can get used to them I'll certainly get used to the taste.
Neutral	The texture bothers me a little whether cooked or raw. It is overall quite interesting. Texture was a bit rough but was marginally improved in the cooked dish. I would say the dune spinach doesn't add or take away from the taste. Where it does add is with the texture that is different from other vegetables. Strong, salty and a little bitter taste but goes well with the onions and extras that contribute to the strong taste that make it more appealing or acceptable. The taste of the dune spinach does not fit the flavor profile of the rest of the dish. The rough texture is a bit strange. Reminds me of being liked by a cat on the inside. Raw form of dune spinach needs more ingredients to be paired with it. The cooked one I can cope with it. Sharp taste.

Table C.2: Respondents' attitudes towards the texture of the *soutslaai* salsa and *smoortjie*

Theme	**Responses**
Likes (Raw Texture)	I like the *soutslaai* more than the dune spinach. Both the *soutslaai* is juicy, less sour and has a gentler texture in both cases. the smoortjie options were very delicious. I've now had four portions. Gave more body to the recipe texture was good. Both raw and cooked were great. Cooked *soutslaai* was close to that of mushrooms in their texture. Very delicious, the *soutslaai* compliments the dish very well and adds a crunchy texture I love it. Tender and firm. Really Pleasant taste and texture Raw *soutslaai* tastes much better than the raw dune spinach. Love it raw and cooked Uncooked and cooked, the vegetable was very delicious. The texture is much better than the dune. The texture is better for this one. Still weird. Takes getting used to.
Dislikes (Raw Texture)	I did not enjoy the raw one
Likes (Cooked Texture)	The saltiness of the leaves was very nice. I like the *soutslaai* more than the dune spinach. Cooked *soutslaai* blew my mind. Both the *soutslaai* is juicy, less sour and has a gentler texture in both cases. the smoortjie options were very delicious. I've now had four portions. Gave more body to the recipe texture was good. Both raw and good were great. Cooked *soutslaai* was close to that of mushrooms in their texture. This is very similar to the cooked dune spinach. Again, the tomato puree with the chilly makes the dish very enjoyable. The extra crunch even though it's still cooked is also a nice crunch. Very delicious, the *soutslaai* compliments the dish very well and adds a crunchy texture I love it. Tender and firm. Really Pleasant taste and texture the cooked one was fantastic not over cooked, *lekker* crunchy, mouth-watering and tasty Texture is a little bit gooey but still love the taste of the combination Sweeter when cooked and also juicier when cooked. Would buy it at the shop. The taste was much better; however, the challenge is that I'm not used to the kind of plants. Love it raw and cooked Uncooked and cooked, the vegetable was very delicious. The texture is much better than the dune.

Appendix D

Normality Assumption and Statistical Test Output

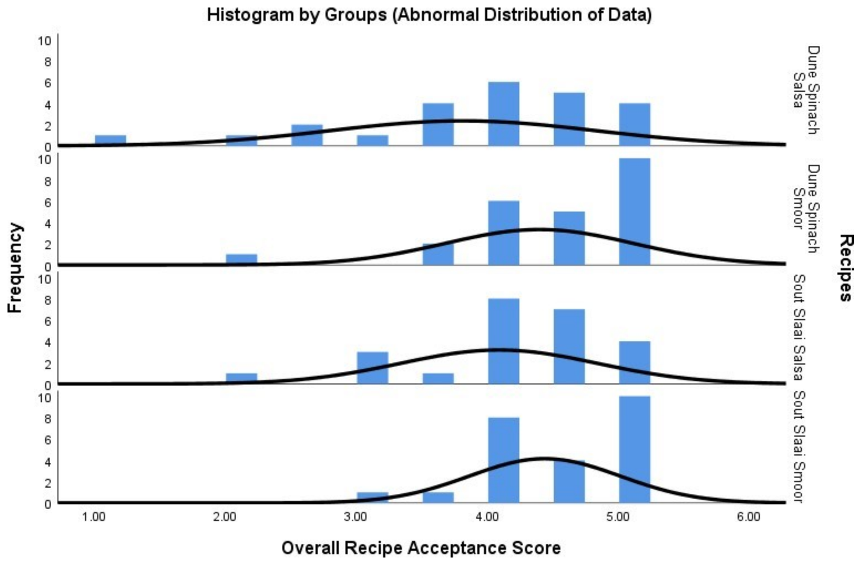


Figure D.1: Histograms showing how normality curve fits the data for the acceptance score for each recipe

Table D.1: Skewness and kurtosis values for the dune spinach and *sout slaai* recipes

Recipe	Skewness	Kurtosis
Dune spinach salsa	-1.12 (SE = 0.47)	1.21 (SE = 0.92)
Dune spinach *smoortjie*	-1.68 (SE = 0.47)	3.99 (SE = 0.92)
Sout slaai salsa	-1.04 (SE = 0.47)	1.25 (SE = 0.92)
Sout slaai smoortjie	-0.66 (SE = 0.47)	0.21 (SE = 0.92)

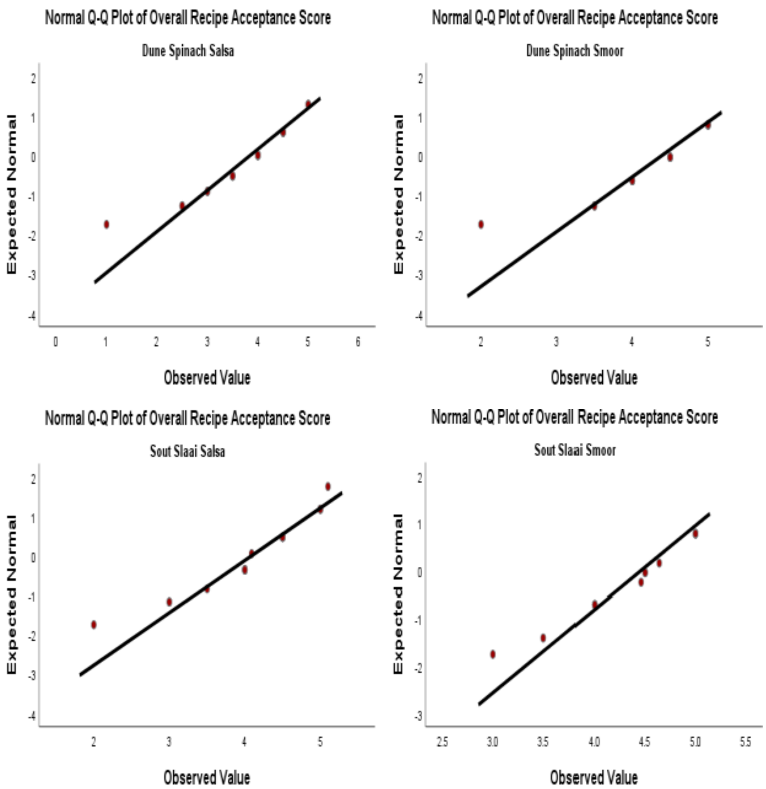
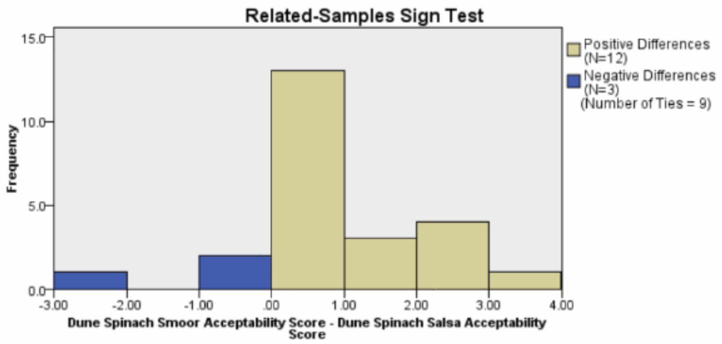


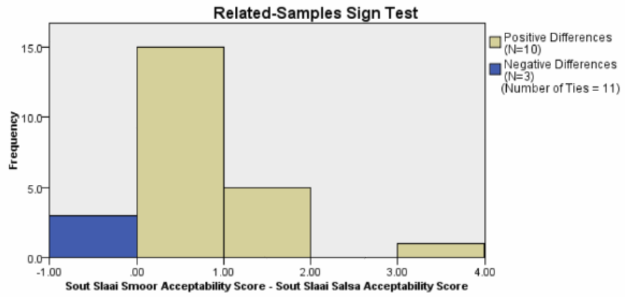
Figure D.2: Q-Q plots for the acceptance scores for each vegetable



Total N	24
Test Statistic	12.000
Standard Error	1.936
Standardized Test Statistic	2.066
Asymptotic Sig. (2-sided test)	.039
Exact Sig. (2-sided test)	.035

1. The exact p-value is computed based on the binomial distribution because there are 25 or fewer cases.

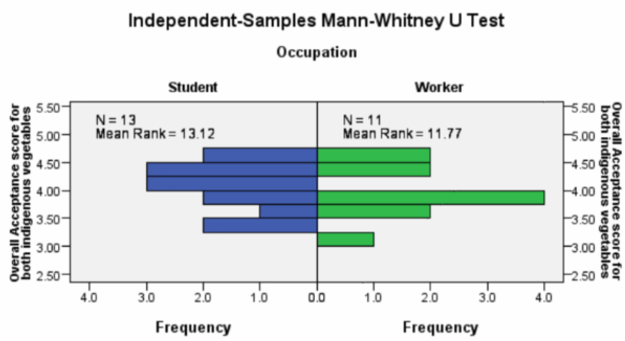
Figure D.3: SPSS generated histogram with frequency of negative and positive differences in acceptability score for the dune spinach salsa and *smoortjie* and exact statistical significance of median acceptability



Total N	24
Test Statistic	10.000
Standard Error	1.803
Standardized Test Statistic	1.664
Asymptotic Sig. (2-sided test)	.096
Exact Sig. (2-sided test)	.092

1. The exact p-value is computed based on the binomial distribution because there are 25 or fewer cases.

Figure D.4: SPSS generated histogram with frequency of negative and positive differences in acceptability score for the sout slaai salsa and smoortjie and exact statistical significance of median acceptability



Total N	24
Mann-Whitney U	63.500
Wilcoxon W	129.500
Test Statistic	63.500
Standard Error	17.208
Standardized Test Statistic	-.465
Asymptotic Sig. (2-sided test)	.642
Exact Sig. (2-sided test)	.649

Figure D.5: SPSS generated Mann-Whitney U test for overall acceptance mean rank score for students and working professionals

Appendix E

Correlation Tables

Table E.1: Correlation table of overall acceptance score for dune spinach by overall acceptance score for *sout slaai*

			Overall acceptance score for dune spinach	Overall acceptance score for *sout slaai*
Spearman's rho	overall acceptance score for dune spinach	Correlation Coefficient	1	.514*
		Sig. (2-tailed)	.	0.01
		N	24	24
	overall acceptance score for *sout slaai*	Correlation Coefficient	.514*	1
		Sig. (2-tailed)	0.01	.
		N	24	24

Table E.2: Correlation table of overall acceptance of both indigenous vegetables by how often respondents would eat these vegetables

			Overall acceptance score for both indigenous vegetables	How often would you eat these vegetables?
Spearman's rho	overall acceptance of both vegetables	Correlation Coefficient	1	.362
		Sig. (2-tailed)	.	0.082
		N	24	24
	How often would you eat these vegetables?	Correlation Coefficient	.362	1
		Sig. (2-tailed)	0.082	.
		N	24	24

Table E.3: Correlation table of overall acceptance of both indigenous vegetables by (purchasing intent) likelihood of respondents paying for dune spinach and *sout slaai*

			Overall acceptance of both indigenous vegetables	Would you pay for these vegetables?
Spearman's rho	overall acceptance of both indigenous vegetables	Correlation Coefficient	1.000	.698**
		Sig. (2-tailed)	.	0.000
		N	24	24
	Would you pay for these vegetables?	Correlation Coefficient	.698**	1.000
		Sig. (2-tailed)	0.000	.
		N	24	24

Table E.4: Correlation table of Consumption intent and purchasing intent

			How often would you eat these vegetables	Would you pay for these vegetables?
Spearman's rho	How often would you eat these vegetables?	Correlation Coefficient	1	.601**
		Sig. (2-tailed)	.	0.002
		N	24	24
	Would you pay for these vegetables?	Correlation Coefficient	.601**	1.000
		Sig. (2-tailed)	0.002	.
		N	24	24

Appendix F

Generic Soil Analysis Norms

SOIL ANALYSIS NORMS

ANALYSIS	MEASUREMENT UNITS	OTHER CRITERIA	MEASURED VALUES			PROBLEM ASSOCIATED WITH	
			LOW	ACCEPTABLE	EXCESSIVE	LOW VALUE	EXCESSIVE VALLUE
pH		Measured in water (H 0)	< 6.5	6.5 - 7.5	> 7.3	Poor growth, impeded fine root development, reduced P availability	Low availability of nutrients
		Measured in Potassium chloride (KCl)	< 5.5	5.5 - 6.5	> 8.3	Poor growth, impeded fine root development, reduced P availability	Low availability of nutrients
Organic carbon	Percentage (%)	Soil texture - for soil <5% clay, use 0.5-1.0% as acceptable norm	< 0.5	0.8 - 1.5	> 1.5	Soil compaction occurs easily	Excessive vigour, high costs to maintain
Electrical conductivity (EC)	mS/cm			1.0 - 2.5	> 4		High salt concentration
Resistance	Ohm (Ω)		< 100	> 400		Unsuitable for crops; salinity levels too high	
Phosphorous (P)	mg/kg (ppm)	Soil with clay content 0 - 6 % (sandy) Soil with clay content 6-15 % (loamy) Soil with clay content > 15% (clay)	< 20 < 25 < 30		>150 >170 >200	Phosphor requirement	Decreased Zn-uptake
Phosphorous (P O)	mg/kg (ppm)	Soil with clay content 0 - 6 % (sandy) Soil with clay content 6-15 % (loamy) Soil with clay content > 15% (clay)	< 47 < 58 < 70			Phosphor requirement	Decreased Zn-uptake
Potassium (K)	mg/kg (ppm)	Ca ² > 5 cmol(+)/kg, Resistance < 500 Ω, pH (KCl) > 6 or < 5 % clay	< 70	70 - 120		Potassium requirement	Decreased Mg uptake
Potassium (K O)	mg/kg (ppm)	Ca ² > 5 cmol(+)/kg, Resistance < 500 Ω, pH (KCl) > 6 or < 5 % clay	< 85	85 - 145		Potassium requirement	Decreased Mg uptake
Exchangeable Potassium (K)	% of Cation Exchange Capacity (CEC)	Ca ² < 5 cmol(+)/kg, Resistance < 500 Ω, pH (KCl) < 6 and where > 5 % clay	< 4	4 - 6		Potassium requirement	Decreased Mg uptake
Exchangeable Calcium (Ca ²)	cmol/kg	pH < 5.5 and < 5 % clay	<2.00	2.00-6.00	>6.00	Potential Ca deficiency	Potential salinity
Exchangeable Calcium (Ca ²)	% of Cation Exchange Capacity (CEC)	pH < 5.5 and > 5 % clay	< 60	65 - 85		Lime requirement	
Exchangeable Magnesium (Mg ²)	cmol/kg	< 5 % clay	<0.5	0.50-2.00	>2.00	Potential Mg deficiency	Potential salinity
Exchangeable Magnesium (Mg ²)	% of Cation Exchange Capacity (CEC)	pH < 5.5 and > 5 % clay	< 15	15 - 20	>20	Magnesium requirement	Soil structural problems/compaction
Exchangeable Sodium (Na)	% of Cation Exchange Capacity (CEC)			< 10	>15		Soil structural problems/compaction
Exchangeable Sodium Percentage (ESP)*		Resistance < 300 Ω Well drained soil, pH(KCl) > 6.5, free lime present			> 15 < 15	Gypsum requirement Fresh irrigation water will leach salinity	
Exchangeable Sodium (Na)	cmol/kg	Sand Sandy Loam Loam Silt Loam			>0.6 >1.2 >1.5 >3.15		
Calcium : Magnesium ratio		pH(KCl) < 5.5	< 5 :1	4 : 1	> 5 : 1	Apply dolomitic lime	Apply Calcitic lime
Total N	Percentage (%)	Organic matter (C) in soil	<0.06	0.06 - 0.15	>0.15	Poor vegetative growth expected due to deficient N availibility	Excessive vegetative growth due to excessive N availability. Crops prone to disease infection.
Mineral Nitrogen (NH_4^+-N + NO_3^--N) **	mg/kg (ppm)	Soil analysis results are not very useful due to dynamic nature of N mineralisation processes. Norms are the sum of NH_4^+ & NO_3^-	<6	6-15	>15		
Chloride (Cl)	mg/kg (ppm)			< 35	> 55		Cl toxicity, possible salinity
TRACE ELEMENTS & SULPHUR ***							
Zinc (Zn)	mg/kg (ppm)	pH > 6.5	< 1.0			Zn deficiency	
Boron (B)	mg/kg (ppm)		< 0.5	1 - 3	> 3.8	B deficiency; foliar application	B toxicity; lime application
Manganese (Mn)	mg/kg (ppm)	pH(KCl) > 5.5 pH(KCl) < 5.5	< 5 < 5	5 - 60 5 - 60	> 200 > 60	Mn deficiencies; foliar application	Mn toxicity, lime application if pH<5.5
Sulpher (S)	mg/kg (ppm)	If soil C > 0.8%, no S required. S in irrigation water & fertilisers.	<20	20-200	>200	S deficiency	
Copper (Cu)	mg/kg (ppm)		< 5	5 - 25	>25	Copper deficiency possible	Earthworm activity affected

NOTES

*** Exchangeable Sodium percentage (ESP):** This value is expressed as a percentage of the sum of the total basic cations (Ca ² +Mg ² +K + Na), or S-value, and gives an indication of the type of salinity in the soil.
ESP > 15 % and resistance < 300 Ω = Sodium brackish soil (ameliorated by the application of Gypsum)
ESP < 15 % and free lime present = Salt brackish soil (ameliorated by using fresh irrigation water)
ESP > 15 % and free lime present = Salt sodium brackish soil (ameliorated by using fresh irrigation water)

**** Mineral Nitrogen (N):** The extraction methods used for determination of nitrogen in soil do not give an indication of the plant available nitrogen for the plant. Vigour norms are used for nitrogen fertilizer applications.

***** Trace elements** Trace elements are required in very small amounts by the vine and therefore the best method of application is by foliar sprays.
Foliar sprays are recommended only when deficiency symptoms are seen. Toxicity symptoms are normally only alleviated by the application of lime to increase soil pH.

Compiled by Pieter Raath & Andrew Teubes