Conserving local knowledge of traditional leafy vegetables and assessing their potential in poverty alleviation and water conservation in the Vhembe district of Limpopo Province

Report
to the Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND

Traditional leafy vegetables (TLVs), also known as African leafy vegetables or Indigenous leafy vegetables, are plants that have evolved with communities whose leaves, immature green pods, stems, roots, seeds, flowers, fruits or even bark are socially accepted and consumed as vegetables by the communities (Kimiywe et al., 2007; Nguni & Mwila, 2007). Schippers (2000) defined African indigenous vegetables as plant species whose leafy parts (including young, succulent stems and immature fruit) are consumed as vegetables. Asfaw (2001), on the other hand, defined indigenous vegetables as "edible" plants that are biologically indigenous to an area. Traditional leafy vegetables are an important part of farming and consumption systems throughout Africa and play a crucial role in alleviating poverty, reducing hunger, and combating malnutrition. The production and consumption of these leafy vegetables have been viewed by many as another means to address the Sustainable Development Goals (SDG) as set by the United Nations General Assembly in 2015; namely, SDG 1 (No poverty), SDG 2 (Zero hunger), and SDG 3 (Good health and Well-being). Several authors have reiterated that traditional leafy vegetables have the potential to become commercially viable since they are readily available. Traditional leafy vegetables are easy to grow and can thrive under harsh conditions with fewer inputs than exotic vegetables because they are adapted to the local climate (Kimiywe et al., 2007; Cunningham et al., 1992; van Rensburg et al., 2007; Ekesa et al., 2015). These leafy vegetables come into production within a fleeting period of time and can be harvested within three to four weeks after planting. Therefore, promoting the production of traditional leafy vegetables can also help reduce water use, since most of these vegetables are drought-tolerant and require fewer inputs. As a result, cultivating and selling traditional leafy vegetables by smallholder farmers can assist them to earn extra income and thereby improve their standard of living. Commercialisation of indigenous vegetables can also create job opportunities and reduce the unemployment rate.

Traditional leafy vegetables have been reported to be an important source of essential nutrient elements such as iron, zinc, and calcium and are rich sources of carbohydrates, proteins, fibre and vitamins (Cunningham et al., 1992; Nguni & Mwila, 2007). These leafy vegetables contain dietary phytochemicals such as phenolic compounds, flavonoids, dietary fibre, carotene, and glucosinolates, which provide health and nutritional benefits to consumers. In addition to their nutritional value, traditional leafy vegetables have been reported to have medicinal benefits. Consumption of TLVs has been reported to assist in the management of illnesses such as malaria, diarrhoea, anaemia, colds and coughs, skin infections, malnutrition, and high blood pressure. Several authors have stressed the nutritional and medicinal value of traditional leafy vegetables (Nesamvuni et al., 2001; Steyn et al., 2001; Jansen van Rensburg et al., 2004). Furthermore, traditional leafy vegetables are considered drought-tolerant and can thrive in harsh environments with minimal inputs. Research has shown that most traditional leafy vegetables can still achieve high nutritional yields even if the full crop requirement (ETc) is reduced by 40%. Therefore, encouraging the mass production of traditional leafy vegetables can play a significant role in conserving water, as exotic vegetables require a large volume of water.

Despite the above-mentioned advantages, most people (Mavengahama, 2013) still neglect traditional leafy vegetables. This negligence was exacerbated by the introduction of exotic vegetables, which left many of the traditional leafy vegetables ignored. As a result, the potential of traditional leafy vegetables to contribute to food and nutrition security is compromised and remains stagnant. According to Mabhaudi et al. (2017), low production and consumption of indigenous vegetables is related to several factors such as cultural beliefs, lack of high-quality seeds, poor accessibility, lack of in-depth research, lack of production knowledge, and wrong perceptions by youth partly due to high cultivation of exotic vegetables, lack of government intervention, wrong perceptions, and poor marketing (Mavengahama, 2013). According to Mahlangu et al. (2014), most research to date has focused on the utilisation and commercialisation of indigenous vegetables, with little attention to their production techniques. This implies that information regarding the cultivation of indigenous vegetables remains sceptical.

In light of the above, there is a need to collect and document the indigenous knowledge regarding the production and consumption of traditional leafy vegetables before they disappear and are irretrievably lost to future generations (; Steyn et al., 2001; Jansen van Rensburg et al., 2004). The documentation of cultivation techniques will therefore go a long way in stimulating the consumption of traditional leafy vegetables among the communities. Moreover, there is a need to promote the production of traditional leafy vegetables in South Africa and other African countries that are characterised by high rates of poverty, hunger, malnutrition, and unemployment. This study, therefore, aimed to determine the level of indigenous knowledge among local people in the Vhembe district regarding the production, consumption, and sale of traditional vegetables.

AIMS

The project aimed to identify and document native knowledge of traditional leafy vegetables commonly consumed in the Vhembe district. The study was designed to achieve the following objectives:

- to review the existing traditional vegetables grown in the Vhembe district.
- to determine the different types of traditional vegetables grown by the rural communities and their nutritional values.
- to identify traditional vegetables that also have medicinal values.
- to determine the effects of macadamia husk compost and water regimes on traditional vegetables.

METHODOLOGY

The survey was conducted in Vhembe District Municipality (i.e., Thulamela, Makhado, Collins Chabane, and Musina local municipalities). A set of structured questions was used to collect information from respondents regarding their native knowledge of the consumption, production, and sale of traditional vegetables (Appendix 2). A sample of 196 respondents selected through a simple random technique was considered. Frequencies, standard deviations, percentages, and cross-tabulations were calculated using Statistical Package for Social Science (IBM SPSS version 3.1). The differences between the observed data and the expected distribution at the 5% level of significance were tested using a chi^2 ($\chi 2$) test.

RESULTS AND DISCUSSION

The aim of the review was to investigate and highlight the work that has been done on the cultivation and potential benefits of consuming traditional leafy vegetables in the Vhembe district of Limpopo Province, South Africa, and to relate this to what other authors have reported across the African continent. The framework conceptualises the linkages among the three pillars of traditional leafy vegetables: food security, health benefits, and nutritional value. The framework began with the production and utilisation of native leafy vegetables, which is thought to affect the availability and acceptance of traditional leafy vegetables by the people. A large body of literature has been published on how the commercialisation of traditional leafy vegetables has enhanced the income of smallholder farmers. It was noted from the literature that farmers who sell traditional leafy vegetables generate income in the same manner as those who cultivate exotic vegetables. Empirical evidence shows that there are over 46 varieties of traditional leafy vegetables consumed in Vhembe district, including Amaranthus dubius, Amaranthus hybridus, and Amaranthus spinosus, which are considered a positive standard by the people. It was observed from the literature review that food security depends on *Bidens pilosa*, *Cucurbita pepo*, *Cleome gynandra*, *Cleome monophylla*, and *Mormodica foetida*. This review found that consuming an adequate amount of traditional leafy vegetables regularly can reduce the incidence of non-communicable chronic diseases, certain infectious diseases, and metabolic disorders such as obesity. This is because traditional leafy vegetables contain dietary phytochemicals, such as glucosinolates and anticancer compounds, which provide health benefits to consumers. In addition, traditional leafy vegetables are used to treat constipation, fever, haemorrhage, anaemia, kidney failure, as a wound dressing, and as a tapeworm repellent.

A large number of the participants (65%) indicated that they obtained traditional leafy vegetables that they consume from their own home gardens, where they grow voluntarily as weeds. About 14% of participants purchase traditional leafy vegetables from the market, while only 3% collect them from the wild. This highlights the importance of these vegetables in reducing poverty and addressing food insecurity. Approximately 41% of the participants indicated that they cultivate traditional leafy vegetables because they are easy to grow and maintain. Traditional vegetables are known for their ability to grow under harsh environmental conditions with minimal care. The participants were asked to provide a list of traditional leaf vegetables that they plant. About 17% of the participants indicated that they planted African nightshade, while 16% planted Cucurbits, followed by those who planted Mustard (13%) and jute mallow (11%), respectively. People indicated that they consume traditional vegetables for assorted reasons. Most participants (76%) consume traditional leafy vegetables for their health benefits and nutritional value. They have indicated that traditional leaf vegetables provide vitamins (29%), carbohydrates and proteins (12%), minerals (11%), and antioxidants (11%). The majority of the participants (74%) indicated that they do preserve some of these vegetables. Although respondents preserve traditional leafy vegetables, about 26% of participants have indicated a preference for fresh ones. The participants agreed that they preserve traditional leafy vegetables for various reasons. About 49% of respondents preserved traditional leafy vegetables for use during times of need, especially during the drought. About 15% of the participants preserved traditional vegetables to avoid spoilage. Some traditional leafy vegetables have noticeably short shelf lives and must be preserved for future use. About 44% of participants reported using the sun-drying method to preserve traditional leaf vegetables. Cooking and Sun drying methods are preferred by many because they are cheap and convenient.

Some respondents reported irrigating traditional vegetables to improve production. However, irrigation frequency varies from one local municipality to another. The Thulamela local municipality had a high number of respondents who irrigate their vegetables, whereas the Collins Chabane and Makhado local municipalities had a small number of respondents who irrigate their crops. This response is understandable, given that water is scarce in these two local municipalities. A considerable number (29%) of participants get irrigation water from rivers, followed by those who use municipal water (26%) and borehole water (20%). A large number of respondents in Collins Chabane obtained irrigation water from the municipality. This is partly due to the small number of rivers within the Collins Chabane and Makhado local municipalities. The majority of respondents (52%) used the bucket system to irrigate their vegetables, followed by drip (19%) and sprinkler (12%) systems. Although the majority of the respondents use the bucket system, most of the respondents (47%) in the Thulamela local municipality use the drip irrigation system to irrigate their traditional leafy vegetables. Only 3% of the respondents use a flood irrigation system. This system is out of favour because it has so many disadvantages, such as accelerating soil erosion and nutrient mining. The respondents listed traditional leaf vegetables they believe are drought-tolerant and suitable for planting in water-limited areas. Approximately 11% of the respondents listed Jute mallow as one of the traditional leaf vegetables that requires less water. This was followed by Amaranths (10%) and Cucurbits (8%), respectively. About 29% of the participants believed that if the government provided them with water, they could produce massive quantities of traditional leafy vegetables.

Among the participants, some sell traditional leafy vegetables for various reasons. Approximately 41% indicated that they sell these vegetables primarily to generate income. The most profitable traditional leafy vegetables mentioned in the Vhembe district include African nightshade (23%), amaranth (14%), and mustard (9%). Most of the respondents (35%) indicated that they sell their products in a formal market while about 34% sell traditional leafy vegetables by the roadside (34%). Only 16% move from house to house, selling traditional leafy vegetables. It was interesting to note that there are some respondents who have contracts to supply traditional leafy vegetables to retailers such as Boxer, Spar, Roots, Pick ’n Pay and Shoprite. This can serve as motivation for others who want to produce traditional leaf vegetables for sale. Most respondents indicated that vegetable spoilage (10%), non-paying customers (9%), lack of market (8%) and transport cost (8%) were the most challenging factors when selling traditional leaf vegetables in the study area. Jute mallow tops the list as the most favoured traditional leafy vegetable, followed by Mustard (13%), amaranth (12%), Cucurbit (12%), Okra (10%) and African nightshade (10%). About 60% of participants agreed that cultivating traditional leafy vegetables could alleviate poverty in the study area. About 49% of the respondents sell a bunch of traditional leaf vegetables at between R1,00 and R5,00, while 31% range their prices between R6,00 and R12,00.

The study revealed that macadamia husk compost (MHC) significantly enhanced soil chemical properties and the nutritional quality of jute mallow. Applying 30 t ha^{-1} and 60 t ha^{-1} of MHC improved soil nutrients, plant growth and yield, with 30 t ha^{-1} MHC often matching the benefits of 60 t ha^{-1} MHC. This improvement led to increased antioxidant activity and flavonoid content in jute mallow, indicating a saturation effect in which moderate amendment is sufficient. Although NPK also increased flavonoid levels, its effect was less notable than that of MHC, suggesting that organic amendments enhance soil biological activity. The application of water significantly affected the growth and phytochemicals of jute mallow. Reduced irrigation negatively affected plant quality by lowering antioxidant levels. The findings emphasise the importance of integrating organic amendments, such as macadamia husk compost, at optimal moisture levels to improve soil health and nutritional quality in jute mallow, highlighting 30 t ha^{-1} MHC as an efficient choice for sustainable leafy vegetable production. Irrigation treatments had a significant effect on FRAP assay, total flavonoid content (TFC), total phenolic content (TPC), and moisture. However, applying water at 60% FC, decreased jute mallow FRAP assay by 16% (3.302 vs 2.788 uM), whereas irrigation at 30% decreased FRAP by 27% (3.302 vs 2.418 uM), relative to the control. Moreover, relative to the control, irrigation at 30% FC decreased moisture and total flavonoid content by 57% (29.27 vs 12.64%), and 29% (11.46 vs 8.12 ug/ml), respectively. However, this was contradictory to a study on medicinal plants, where water deficit (moderate water stress) resulted in a slight increase in phenolic content and leaf flavonoids, though under severe drought, the results were not uniform. This highlights that not all species respond in a comparable way to water stress. The interaction between fertiliser and irrigation treatments had a significant effect on FRAP, TFC, TPC, and moisture content ($P<0.001$).

GENERAL

The overall aim of the project was to determine and document indigenous knowledge of traditional leafy vegetables adapted to the growing conditions of the Vhembe district. The study has achieved all its objectives. Indigenous knowledge regarding the production, consumption and selling of traditional leafy vegetables in Vhembe district was recorded and documented (Objective 1). The information was gathered using a survey conducted in four local municipalities. Traditional leafy vegetables commonly consumed were identified. The results concurred with those of other authors who have conducted similar work in the Vhembe district (Objectives 2 and 3). The effect of macadamia husk compost and water regimes on jute mallow was investigated. Just like other plants, growth, yield and phytochemical compounds of jute mallow were influenced by the application of water and compost (Objective 4). However, there is a need to determine the water requirements of different traditional leafy vegetables, as this information is currently lacking.

CONCLUSIONS

From the results of this project, it was concluded that people in the Vhembe district consume, produce, and sell traditional leafy vegetables for various reasons. People have extensive native knowledge of the cultivation and use of traditional leafy vegetables. People are conscious about the health and nutritional benefits of traditional leafy vegetables. However, this knowledge is not well-documented and lacks scientific support. It was concluded that encouraging the cultivation, consumption, and sale of traditional leafy vegetables can help address challenges such as food insecurity, hunger, and poverty. If properly executed, the production and sale of traditional leafy vegetables can generate additional income for smallholder farmers, create jobs, and reduce the unemployment rate.

RECOMMENDATIONS

The study recommends that research institutions, Non-profit organisations, academic institutions, and policymakers collaborate to ensure the integration of traditional leafy vegetables into food systems. Public awareness regarding the cultivation, consumption, and sale of traditional leafy vegetables must be created. The importance of traditional leafy vegetables must be recognised and promoted to increase their production and consumption. If the potential of traditional leafy vegetable crop production is realised for large-scale commercial ventures, further financial investment would follow, and the involvement of a younger, entrepreneurial generation would be developed. The health and nutritional values of traditional vegetables must be scientifically proven rather than mere myth, which calls for a robust investigation. There is a need to investigate the effect of processing and preservation methods on the quality and taste of traditional leafy vegetables. Providing water in the Vhembe district can encourage farmers to produce and sell traditional leafy vegetables. The establishment of pharmaceutical companies in the Vhembe district is recommended. Such an initiative could lead to the production of traditional leafy vegetables on a large, intensive scale. There is a need to conduct a detailed study of the water-use efficiency of the most commonly used traditional leafy vegetables in the Vhembe district. The results of this study will help people determine each crop's water needs, thereby helping save water.

SCOPE OF THE PROJECT

The project to conserve indigenous knowledge of traditional leafy vegetables aims to document, preserve, and promote indigenous practices related to cultivation, consumption, and sale to enhance poverty alleviation and water conservation. The significance of this project extends beyond the consumption of traditional leafy vegetables for nutritional and medicinal benefits. The cultivation of traditional leafy vegetables can also play a crucial role in poverty alleviation and water conservation. This project seeks to bridge this gap by documenting indigenous knowledge and transferring it to younger generations to ensure job creation, food security and poverty alleviation.

In-Scope Activities

The project focused on the following activities within the defined area:

- **Literature review:** A literature review was conducted in order to review the work that was already done and to establish the existing gaps regarding the production, consumption and selling of traditional leafy vegetables.
- **Surveys:** Conduct face-to-face interviews with the producer, consumer and sellers of traditional leafy vegetables to identify indigenous vegetables.
- **Documentation:** Collect and document indigenous knowledge regarding the cultivation, consumption and selling of traditional leafy vegetables. Establish a guidebook of the most commonly consumed traditional leafy vegetables, including their local names, uses, nutritional values, and medicinal benefits.

- **Capacity building:** Organise community training sessions where the cultivation techniques will be demonstrated to the people. The project involved an MSc student in human development.

- **Target Vegetables**

  The project will focus on, but is not limited to, the most frequently consumed traditional leafy vegetables in Vhembe district.

Out-of-Scope Activities

- Promoting the production and selling of traditional leafy vegetables on both informal and formal markets.
- Establishing policies that promote the production and commercialisation of traditional leafy vegetables

Expected Outcomes.

- Increased knowledge on the cultivation and selling of traditional leafy vegetables.
- Documented and accessible indigenous knowledge for future research.
- Creating awareness on the benefits of consuming traditional leafy vegetables.

Target beneficiaries

- Policy makers.
- Smallholder farmers in the rural and peri-urban areas.
- Agricultural advisors, technicians and researchers.

Project Deliverables

- A report submitted to the Water Research Commission.
- MSc Thesis
- Guidebook on the most frequently consumed traditional leafy vegetables
- Peer reviewed articles

Constraints

- **Limited budget:** Only a survey and one field trial were conducted due to budget constraints.

- **Research gaps**: The study explored several gaps that need further investigation:

  There is limited information on the water-use efficiency of traditional leafy vegetables,

  The respondents in the study area preserve and process traditional leaf vegetables, however, there is no information regarding the effects of different preservation method on the quality and taste of these vegetables.

  There is a need to do cost analysis of using macadamia husk compost to increase yield and water conservation.

  There are no policies that are directed to the enhancement of the utilisation and commercialisation of traditional leafy vegetables

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Extension officers	Limpopo Department of Agriculture and Rural Development (LDARD)
Smallholder farmers	Vhembe District Municipality (VDM

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ACRONYMS, ABBREVIATIONS & UNITS

°C	Degree Celsius
ANOVA	Analysis of Variance
ARC	Agricultural Research Council
BC	Before Christ
C	Carbon
Ca	Calcium
CABI	Centre for Agriculture and Biosciences International Archives
Cm	Centimetre
Cv	Covariance
CV	Covariation
DAFF	Department of Agriculture, Forestry and Fisheries
DAP	Day After Planting
DAT	Days after Transplanting
DoA	Department of Agriculture
EC	Electrical Conductivity
Evap.	Evapotranspiration
FAO	Food and Agriculture Organisation
FC	Field Capacity
Fe	Iron
g	Grams
gkg-1	Grams Per Kilogram
ha	Hectare
IBM	Institute of Business Management
ILV'S	Indigenous Leafy Vegetables
ISCW	Institute for Soil Climate and Water
Kg	Kilogram
Km2	Kilometre Square
LSD	Least Significance Difference
m	Meter
MaxRH	Maximum Relative Humidity
mg	Milligrams
Mg/kg	Milligrams Per Kilogram
MHC	Macadamia Husk Compost
MinRH	Minimum Relative Humidity
mm	Millimetre
N	Nitrogen
Na	Sodium
NPK	Nitrogen, Phosphorus, Potassium
OC	Organic carbon

OECD	Organisation for Economic Co-operation and Development
P	Phosphorus
PhD	Doctor of Philosophy
SADC	Southern Africa Development Cooperation
SDG's	Sustainable Development Goals
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSA	Sub Saharan Africa
t ha-1	Tons Per Hectare
TFC	Total Flavonoid Compound
TLV'S	Traditional Leafy Vegetables
TPC	Total Phenolic Compound
TSC	Tropical and Subtropical Crops
TVET	Technical and Vocational Education and Training
µg/l	Micrograms Per Liter
µM	Micrometre
UN	United Nations
VDM	Vhembe District Municipality
Viz	Namely
WRC	Water Research Commission
X2	Chi Square
Zn	Zinc

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

Traditional leafy vegetables are pivotal to food security, health, and income generation, especially in Africa, including South Africa. Despite these advantages, most people (Mavengahama, 2013) still largely neglect traditional leafy vegetables. This negligence was exacerbated by the introduction of exotic vegetables, which left many of the traditional leafy vegetables ignored. As a result, the prospects of traditional leafy vegetables are compromised and remain stagnant. According to Mabhaudi et al. (2017), the underutilisation of traditional leafy vegetables is related to several factors, including cultural beliefs, limited accessibility, limited in-depth research, limited knowledge of production, and incorrect perceptions among youth. Furthermore, negative perceptions of traditional leafy vegetables have favoured the cultivation and consumption of exotic vegetables while limiting exposure to traditional leafy vegetables.

However, there seems to be a gradual spiral in the utilisation of traditional leafy vegetables, especially in the rural and semi-rural areas, owing to their health and nutritional benefits. Consequently, the centre of attention has shifted to fostering the cultivation and utilisation of traditional leafy vegetables within rural farming systems. Many authors have attributed this increase to the important roles that indigenous vegetables play in human health, nutrition, and income generation (Senyolo et al., 2014; Mayekiso & Mditshwa, 2017). Utilisation of traditional leafy vegetables is an integral part of the Sustainable Development Goals (SDG 1, 2 and 3) of the United Nations (UN) General Assembly, which emphasised ending poverty, improving nutrition, ending hunger, achieving food security, promoting sustainable agriculture and ensuring healthy lives (United Nations, 2015). According to Muhanji et al. (2011) and Kwenin et al. (2011), traditional leafy vegetables have the potential to become commercially important because they are readily available, inexpensive to cultivate, and well-suited to harsh environments. According to Pitso & Lebese (2014), the commercialisation of indigenous vegetables could encourage their cultivation by smallholder and subsistence farmers. However, the fact that most people still source indigenous vegetables from the wild poses a serious challenge to their commercialisation. This calls for the government and researchers to encourage farmers to establish traditional leafy vegetable gardens on their homesteads or within existing irrigation schemes.

Although a lot of work has been reported on traditional leafy vegetables in South Africa, little has been done on cultivation techniques, largely due to a lack of knowledge, in-depth research, and strategies to encourage their cultivation. According to Mahlangu et al. (2014), much research conducted so far has focused on the utilisation and commercialisation of indigenous vegetables, with little attention to their production techniques. This implies that information regarding the cultivation of indigenous vegetables remains unknown. This review, therefore, sought to fill this research gap by documenting and conserving information on the cultivation, utilisation, and marketing of traditional leafy vegetables. This information will contribute significantly to the body of literature, offering new insights into the cultivation and consumption patterns of indigenous vegetables. This review aimed to explore, highlight, and document some of the work done on the cultivation and potential benefits of consuming traditional leafy vegetables in the Vhembe district. Documentation of cultivation techniques and consumption patterns of traditional leafy vegetables will therefore encourage and enhance the consumption of indigenous vegetables among the communities.

1.2 PROJECT AIMS

The project aimed to identify and document native knowledge of traditional leafy vegetables commonly consumed in the Vhembe district. The study was designed to achieve the following objectives:

- to review the existing traditional vegetables grown in the Vhembe district.
- to determine the different types of traditional vegetables grown by the rural communities and their nutritional values.
- to identify traditional vegetables that also have medicinal values.
- to determine effects of macadamia husk compost and water regimes on traditional vegetables.

1.3 SCOPE AND LIMITATIONS

This study was conducted to determine and document indigenous knowledge of traditional vegetables adapted to the growing conditions of the Vhembe district. The investigation focused on traditional vegetables because their consumption has been linked to improved health, food security, and poverty alleviation. The aspects investigated were the respondents' feedback on the cultivation, consumption, and selling of traditional vegetables. The study was conducted in four local municipalities in the Vhembe District, Limpopo Province, South Africa. The study's respondents were limited to 196 people, selected through random sampling. To gather information, each participant was given a structured questionnaire to answer. Collected data was cleaned, coded, and analysed using the SPSS program (IBM SPSS version 3.1). As this is a survey, the investigation has potential limitations, including the possibility of influencing participants' responses toward specific categories, which could limit response diversity. Some of the respondents are very reserved and find it difficult to divulge all the necessary information.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Although there is plenty of information on traditional leafy vegetables in South Africa, little has been researched on their cultivation, largely due to a lack of high-quality planting materials, in-depth research, and strategies to encourage their cultivation. According to Mahlangu et al. (2014), most research conducted to date has focused on the utilisation and commercialisation of indigenous vegetables, with little attention to their production techniques. This implies that information regarding the cultivation of indigenous vegetables remains unknown. This review, therefore, sought to fill this research gap by documenting and conserving information on the growing, utilisation, and marketing of traditional leafy vegetables. This information will contribute significantly to the body of literature, offering new insights into the cultivation and consumption patterns of indigenous vegetables. This review aimed to explore, highlight, and document some of the work done on the cultivation and potential benefits of consuming traditional leafy vegetables in the Vhembe district. Documentation of cultivation techniques and consumption patterns of traditional leafy vegetables will therefore encourage and enhance the consumption of indigenous vegetables among the communities.

2.2 LITERATURE SEARCH METHODOLOGY

The review adopted a mixed-method review approach (Page et al., 2021). Preference was given to the literature from the African continent, particularly South Africa. Google Scholar, Scopus, and EBSCOhost were used to search for information. Theses and dissertations from various universities were also used. The major search terms used include, but are not limited to, indigenous, vegetables, African indigenous, African vegetables and traditional vegetables. However, the literature search in the database was not restricted to specific years. As such, about 196 articles were cited in the text. However, the review begins with a conceptual framework on the production and consumption of traditional leafy vegetables, as well as their impact on people's livelihoods.

2.2.1 A conceptual framework for the cultivation and consumption of traditional leaf vegetables

The purpose of this conceptual framework, as alluded to in Figure 1, is to show the linkage among food security, health, nutrition, poverty alleviation and their determinants. The framework conceptualises the linkages that exist amongst the three pillars of indigenous vegetables, which are food security, health benefits and nutritional values. The framework begins with the production and consumption of traditional leafy vegetables, which in turn affect food security, health and livelihood of the people (Figure 1). Food security highly depends on the availability, accessibility and acceptance of indigenous vegetables by the people. As described by McLachlan (2011), consuming indigenous vegetables promotes good health due to high nutrition. According to Kennedy et al. (2007), consumption of indigenous vegetables forms an integral component of a quality diet.

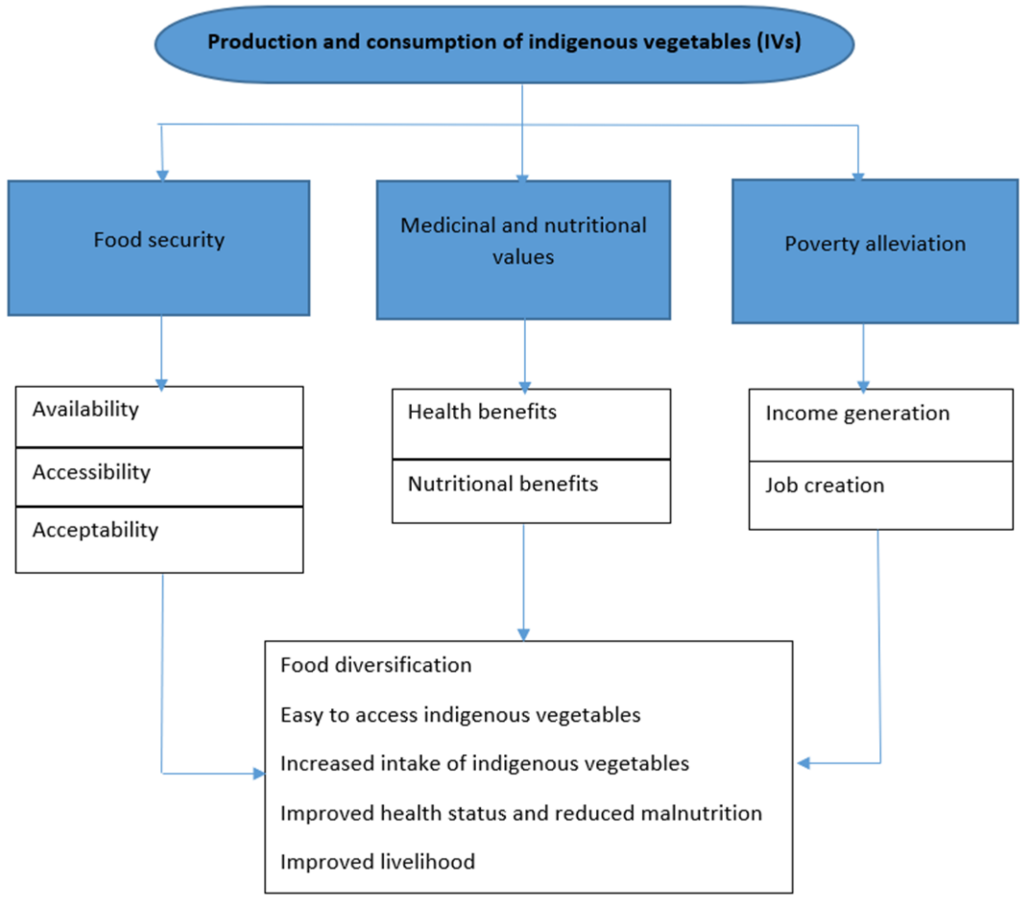

Figure 1. Conceptual framework

Apart from enhancing food security, many farmers grow traditional leafy vegetables to generate income and alleviate poverty (Opondo & Owuor, 2018; Nyaruwata et al., 2018; Mwema & Crewett, 2019). Muhanji et al. (2011) did not find a significant difference between the farmers who produced and sold indigenous crops earned a large amount of income compared to those who produced exotic vegetables. Although some studies have reported the potential of traditional leafy vegetables to alleviate poverty (Nyaruwata et al., 2018; Opondo & Owuor, 2018), South Africa lacks information on the potential for commercialising these vegetables.

2.2.2 Frequently consumed traditional leafy vegetables in Vhembe district

Empirical evidence indicates that there are over 1,000 varieties of traditional leafy vegetables consumed in Africa (Towns & Schackleton, 2018). However, only ±100 traditional leafy vegetables are thought to be available in South Africa. Although there is growing interest in the utilisation of traditional leafy vegetables in the Vhembe district (Nesamvuni et al., 2001), people differ in their preferred types of traditional leafy vegetables. There are many factors that influence people's preference for one indigenous vegetable over another. These factors include location, availability, taste, appearance, culture, social class, age and level of education, amongst others. Several studies have been conducted in and around the Vhembe district, and researchers have listed a number of traditional leafy vegetables that are consumed and those consumed frequently. For example, Mokganya et al. (2019) listed about 46 traditional vegetables consumed in Vhembe district, whereas Maanda and Bhat (2010) listed 46 traditional leafy vegetables in the same area. Although there is no consensus on the number of traditional leafy vegetables consumed in Vhembe district, the literature review noted that most researchers included many of the same traditional leafy vegetables on their lists (Table 1). Traditional leafy vegetables such *Amaranthus dubius*, *Amaranthus hybridus, Amaranthus spinosus, Bidens pilosa, Cucurbita pepo, Cleome gynandra, Cleome monophylla, Mormodica foetida* were reported by all three researchers as being consumed in the Vhembe district (Table 1). However, they differed on some of the traditional leafy vegetables, for example, Mokganya et al. (2019) had *Vigna unguiculata*, *Ipomoea batatas* and *Amaranthus Spinosus* on their list, whereas Nesamvuni et al. (2001) had *Corchorus tridens* on their list. Mbhatsani et al. (2011) included *Mormodica balsamina* on their list, which was not specified either by Nesamvuni et al. (2001) nor Mokganya et al. (2019).

Table 1: Common traditional leafy vegetables frequently utilised in Vhembe district

Scientific name	Local name	R1	R2	R3
Amaranthus dubius	Vowa	X	X	X
Amaranthus esculentus	Vowa	X		
Amaranthus hydridus	Thebe	X	X	X
Amaranthus Spinasus	Mukhuluvhali	X	X	X
Bidens pilosa	Mushidzhi	X	X	X
Cleome monophylla	Mutohotoho	X	X	X
Cleome gynandra	Murudi	X	X	X
Corchorus tridens	Delele	X	X	X
Cucurbita pepo	Phuri	X	X	X
Ipomoea batatas	Murambo			X
Mormodica foetida	Nngu	X	X	X
Mormodica balsamina	Tshibavhe		X	
Solanum retraoflexum	Muxe	X	X	
Vigna unguiculata	Munawa		X	X
R1 (Nesamvuni et al., 2001); R2 (Mbhatsani et al., 2011); R3 (Mokganya et al., 2019)				

2.2.3 Descriptions and uses of frequently consumed traditional leafy vegetables in Vhembe district

Traditional leafy vegetables (TLVs) are known to withstand tropical stresses, such as drought, and exhibit broad adaptation mechanisms (Shayanowako et al., 2021). Each species has its own distinguishing characteristics that set it apart from others, whereas some belong to the same family. These vegetables require minimal management, making cultivation easy, and they usually grow in places where exotic vegetables cannot survive. Many TLVs have limited distribution, resulting in localised knowledge, importance, and consumption of these vegetables in specific regions (Shackleton et al., 2009).

2.2.3.1. Jute mallow (*Corchorus olitorius*)

Jute mallow is commonly referred to as Delele in TshiVenda, and guxe in Xitsonga (Van Rensburg et al., 2007) and can grow tall to a height of 2.4 m and is strongly branched with reddish stems and fibrous (Van Rensburg et al., 2007) (Figure 2). According to Fondio and Grubben (2014), Jute mallow has 50 to 60 species distributed across different climatic regions. Jute mallow is part of the human diet and is a cost-effective supplement and nutrient source (Oyareme et al., 2022). Jute mallow had a total water requirement of 368 mm for the entire growing season. Jute mallow is used as a fibre source in Asia, derived from plant bark, offering long, soft fibre with potential to generate income, create employment, and alleviate poverty (Mahbubul & Saheb, 2017). Furthermore, it provides environmentally friendly fibres, preserving the ozone layer, purifying air, increasing land fertility, and producing biodegradable products and biogas (Mohammad & Sheik, 2012). In light of the above, the production and consumption of jute mallow are expanding in South Africa, prompting interest among South African farmers and researchers (Van Rensburg et al., 2007).

Figure 2: Jute mallow (*Corchorus olitorius*)

2.2.3.2 Green amaranth (*Amaranthus viridis*)

The Amaranthus genus comprises approximately 60 species, most of which are widely distributed as weeds and used for leafy vegetables, grains, or ornamental purposes (DAFF, 2011). The amaranth plant exhibits a range of morphological traits. It encompasses a range of growth patterns, including broad branching and lateral shoots, stems growing horizontally or vertically, with a spectrum of colours of leaves ranging from different shades of red to green (Iftikhar & Khan, 2019). Green amaranth (Figure 3) can grow between 0.3 m and 2 m tall, with distinct leaf markings and terminal and auxiliary inflorescences. This plant is a C4 species that exhibits resilience to adverse climatic conditions and plant pathogens (Manyelo et al., 2022). Amaranth is believed to have originated in America since 6700 BC (DAFF, 2011; Iftikhar & Khan, 2019). Amaranth is a prehistoric crop that is distributed in various temperate and tropical climates worldwide (Adhikari & Paul, 2018). Green amaranth has spread globally, becoming established for food use in Africa, India, Mexico, and Nepal (DAFF, 2011; Milakar et al., 2010). The total water consumption for amaranth for the full growing season amounted to 340 mm (Oelofse & Averbeke, 2012).

Figure 3: Green amaranth (*Amaranthus viridis*)

2.2.3.3. Spider plant (*Cleome gyanandra*)

Spider plant (Figure 4) is commonly referred to as “Murudi” in TshiVenda and acknowledged in large parts of South Africa (Mashamaite et al., 2022), especially in rural areas. Spider plant can grow well in Limpopo, North-West, Mpumalanga, Gauteng, the Eastern Cape, and the Northern Cape of South Africa (Adhikari & Paul, 2018). Its leaves are soft and easy to cook (Onyango et al., 2013). Farmers who currently cultivate spider plants do so for both personal consumption and commercial purposes (Onyango et al., 2002). However, there is also potential for IVs to be grown commercially (Onyango et al., 2002). The spider plant exhibits drought tolerance and thrives in diverse climatic and soil conditions (Mashamaite et al., 2022). This tolerance is due to the crop’s excellent stomatal conductance (Shayanowako et al., 2021). The plant adjusts to soil water scarcity primarily by controlling transpiration through reduced leaf area and, potentially, by regulating stomatal conductance (Masinde et al., 2005; Shayanowako et al., 2021). The crop easily grows in poor soils (Ochuodho et al., 2012). Spider plants require weeding due to their lack of dense foliage and inability to compete with weeds (Ochuodho et al., 2012). Moreover, they can be attacked by flea beetles, pentatomids, locusts, aphids, nematodes, green vegetable bugs, cabbage sawfly, hurricane bugs, and stem borers (Schippers, 2000; Onyango et al., 2013). Spider plant has historically been cultivated utilising traditional farming methods primarily for subsistence purposes (Onyango et al., 2013). Moreover, these methods use readily available organic manure sources on farms (Onyango et al., 2002). Spider plant can be cultivated using mixed cropping methods, which offer numerous advantages in terms of land productivity, soil fertility, and sustainable production (Onyango et al., 2002).

Figure 4: Spider plant (*Cleome gyanandra*)

2.2.3.4. Nightshade (*Solanum nigrum*)

Nightshade is commonly known as “Kophe” in Xitsonga, “Momoli” in Sepedi and “Muxe” in TshiVenda, and it is a member of the Solanum section that has long been considered a toxic species or weed, particularly by developed nations (Mwai et al., 2012). Nightshades (*S. nigrum* complex) are upright, branching herbaceous plants characterised by vibrant green foliage and petite white flowers (Figure 5). *S. nigrum* complex hold significant value as an indigenous leafy vegetable that has been historically consumed by rural communities across the African continent (Mwai et al., 2012). The crop is not drought-tolerant, therefore requires adequate soil moisture and frequent irrigation during dry periods (Schippers, 2002; Masinde et al., 2009). Nightshade crops are cultivated during the winter season (Manyelo et al., 2015). Production of S. nigrum complex requires irrigation using water-saving strategies such as deficit irrigation and partial root drying, which generate root signals and maintain high plant water status (Kang & Zhang, 2004; Sobeih et al., 2004; Liu et al., 2006). Moreover, mulching is recommended in the absence of rain and irrigation intervals can be reduced to 2-3 times a week after seedling establishment (Schippers, 2002). It is recommended to avoid overhead irrigation to prevent disease spread, and frequent weeding is necessary in the early stages (Schippers, 2002).

Figure 5: Nightshade (*Solanum retroflexum*)

2.2.3.5. Butternut (*Cucurbita moschata*)

Butternut is commonly known as “Phuri” or “Thanga” in TshiVenda. Its leaves are simple, with triangular blades about 20-30 cm wide (Wiart, 2013). Pumpkin stems are thick, strong, covered in bristles, and produce several branches with divided tendrils (Jansen van Rensburg et al., 2002; Wiart, 2013). Its leaves are simple, with triangular blades about 20-30 cm wide (Wiart, 2013). It is divided unevenly into five lobes and covered in bristles. The base of the blade is acute and has dentate margins, while the tip is sharp (Jansen van Rensburg et al., 2004; Wiart, 2013). The petiole is robust, succulent, and bristly, reaching 10 cm in length (Thakur et al., 2009; Wiart, 2013). Cucurbits are considered to have economic value in South Africa (Jansen van Rensburg et al., 2004).

Figure 6: Butternut (*Cucurbita moschata*)

2.2.3.6. Balsam pear *(Momordica balsamina*)

Balsam pear (Figure 7) is commonly known as “Tshibavhe” in TshiVenda and belongs to the Cucurbitaceae family (Thakur et al., 2009; Ramalhete et al., 2022). It is renowned for its exceptional capacity to ascend and cling to both trees and shrubs (Thakur et al., 2009). *M.balsamina*, much like *C. maxima*, is a monoecious herb (Deutschlnder et al., 2009). The plant is an herbaceous species that can either be an annual or a short-lived perennial (Deutschlnder et al., 2009). It is found in all provinces of South Africa except for the Western Cape. However, there is a dearth of information about its use (Bharathi & John, 2013). Proper irrigation is crucial for pumpkin production, as under-irrigation reduces yield, increases blossom-end rot, and results in irregularly shaped fruit (Maughan et al., 2015). Over-irrigation increases disease susceptibility, nutrient leaching, and fruit rots, and lowers water-use efficiency, while under-irrigation leads to poor seedling emergence, vine extension, flower abortion, and insect attack (Maughan et al., 2015). The total water demand for *C. maxima* for the entire growth season is about 340 mm (Oelofse & van Averbeke, 2012).

Figure 7: Balsam pear (*Mormodica balsamina*)

2.2.3.7. Cowpeas (*Vigna unguiculata*)

Cowpea, commonly known as "Munawa" in TshiVenda, belongs to the Fabaceae family (Figure 8). The crop has green tender leaves that are harvested and are a crucial leafy vegetable often used in salads, relishes, and alongside potato and maize meals (Sebetha et al., 2010). Varieties of the plant can be short, bushy, prostrate, or vine-like, with canopy heights ranging from 0.61 m- 0.91 m. Stems are approximately 1 cm wide, and those that are upright are hollow and hairless, whereas twining stems are thinner (Sheahan, 2012). It originated from Africa, particularly from West and Central Africa (Ano & Ubochi, 2008; Sheahan, 2012; Ibrahim Sayeed et al., 2017). This vegetable can grow in the wild and it is also cultivated (Sheahan, 2012). Cowpea has been domesticated and cultivated for centuries in Africa and currently, it is grown worldwide (Pasquet, 1998; Sheahan, 2012). Root nodules of cowpea utilise the Vesicular-Arbuscular Mycorrhizal fungus and bacteria, such as Rhizobium, to convert atmospheric nitrogen into ammonia through nitrogen fixation (Duraipandian et al., 2022). It grows well in areas with high temperatures and is regarded as a drought-tolerant crop which can thrive in low fertile soil compared to other crops (Nell & Siebrits, 1992). The total water demand for cowpeas over the entire growing season is 381 mm (Oelofse & van Averbeke, 2012).

Figure 8: Cowpea (*Vigna unguiculata*)

2.2.3.8. Okra (*Abelmoschus esculentus*)

Okra, commonly known as “Delele mandande” in TshiVenda, falls under the Malvaceae family (Binalfew & Alemu, 2016). Okra shows a wide range of growth patterns and levels of branching (Figure 9), including upright, moderate, trailing, and strong branching, and/ or no branching (Binalfew & Alemu, 2016). This indicates diversity in the crop's vigour and branching characteristics. The plant can grow to a height of 4 m (Tong, 2015). Okra accessions exhibit variations in their flowering patterns, leaf characteristics, stem attributes, vein structures, and fruit properties (Binalfew & Alemu, 2016). Moreover, they also display variations in the presence of fine hairs (pubescence) on their stems, leaves, and fruits, ranging from smooth glabrous stems to stems with minor pubescence, and finally to stems with noticeable pubescence (Binalfew & Alemu, 2016; Maldanado-Peralta et al., 2021). The edible fruit has an average volume of 665 mm and is mucilaginous. However, there are some problems with germination (Maldonando-Peralta et al., 2021). The seeds are generally sown at about 5-6 cm depth, and germinating seeds growing on the soil surface encounter mechanical resistance (Sarma & Gogoi, 2015). An average okra crop requires approximately 547 mm of water for its growth (Patil, 2010). The total water demand for okra over the entire growing season is approximately 547 mm (Patil, 2010).

Figure 9: Okra (Abelmoschus esculentus L.)

2.2.3.9. Spindle pod (*Cleome monophylla* L.)

Spindle pod is a member of the Cleomaceae family (Abirami & Vijayashalini, 2018) (Figure 10). It is a weed that grows in farmlands and in the wild. It is commonly known as "Mutohotoho" in TshiVenda (Nesamvuni et al., 2001). The stem of this plant can be either solitary or branching and has an inclined cylindrical shape. It is thickly coated with short glandular and long non-glandular velvety hair. The plant's seeds are strong and almost circular; it also has simple leaves (Shilla et al., 2019). The flowers possess asymmetrical characteristics, are bisexual and nectar-producing, and have a spathulate corolla and asymmetrical petals. The plant requires little care and has low agricultural input costs, such as fertiliser, herbicides, and pesticides (Aworh, 2015). *C. monophylla* grows well during the summer season (Nesamvuni et al., 2001).

Figure 10: Spindle pod (*Cleome monophylla*)

2.2.3.10. Blackjack (*Bidens pilosa*)

Blackjack belongs to the Asteraceae family and is commonly known as "Mushidzhi" in TshiVenda and grow well in almost all provinces of South Africa. *Bidens pilosa* L., is a short-lived perennial herb that is considered as a weed (Arthur et al., 2012; Bartolome et al., 2013; Kuo et al., 2021). The erect herb has a strong taproot of about 1m tall and hairless stems (Figure 11). It has green, compound leaves with 3-5 leaflets, egg-shaped, and broader bases. *Bidens pilosa*, as a weed, it significantly reduces crop yields, with yields in soybean fields reduced by 43 % (CABI, 2016). It is problematic for maize, cabbage, pineapple, and guava crops in Southeast Asia, and is a host to harmful parasites. Blackjack is a traditional African herb used in teas, herbal medicines, and sauces (Chiang et al., 2003). The FAO promoted its cultivation in 1975 due to its easy growth, edible, and safe properties (Bartolome et al., 2013). Blackjack grows well in warm areas with direct sunlight, and moderately dry soil (Kuo et al., 2021). It can thrive in dry and infertile terrain at various elevations and can be propagated through either vegetative propagation using plant cuttings or by sowing seeds (FAO, 1997; Kuo et al., 2021).

Figure 11: Blackjack (*Bidens pilosa*)

2.2.4. Medicinal and nutritional benefits of the frequently utilised traditional leafy vegetables in Vhembe district

The Vhembe district is rich in traditional leafy vegetables with both medicinal and nutritional benefits. These plants are either collected from the natural environment (forests) or cultivated in home gardens (van Rensburg et al., 2007; Thovhogi et al., 2021). Numerous uses of these vegetables in traditional medicine have been documented. Mokganya & Tshisikhawe (2019) documented 13 wild vegetables with ethnomedicinal properties in the Vhembe District Municipality. Consuming adequate amounts of certain dietary phytochemicals regularly has been found to help fight minor and serious diseases, while others provide people with essential nutrients (Sivakumar et al., 2018). Indigenous leaf vegetables contain dietary phytochemicals such as phenolic compounds, flavonoids, dietary fibre, carotene, glucosinolates and vitamins which provide health benefits to the consumers (Mungofa et al., 2022; Sivakumar et al., 2018). However, it is important to acknowledge that different species and parts of traditional leafy vegetables have varying nutritional content for the human diet.

2.2.4.1. Jute Mallow

In folk medicine, jute mallow was used to treat gonorrhoea, chronic cystitis, pain, fever and tumours (Smith, 1985). Furthermore, it can be used as a tonic to treat toothache, diarrhoea, and heart problems (Gruben, 2004). The extracts of *Corchorus olitorius* have been reported to possess antioxidant, anti-inflammatory, hepatoprotective, antihyperlipidemic, immunostimulant, antitumor, antimicrobial, antidiabetic, analgesic, and wound-healing properties, as well as cardioprotective activities (Abdel-Razek et al., 2022). Do et al. (2021) investigated the protective effects of water-soluble extracts of *Corchorus olitorius* leaves on alcohol-induced disruption of the gut-liver axis in mice. The authors concluded that this vegetable can be used as a dietary supplement to help mitigate alcohol-induced liver damage by regulating the gut-liver axis. The leaves of (*Corchorus capsularis* and *Corchorus olitorius*) have been reported to possess the antitumor-promoting activity (Furumoto et al., 2002). Lee et al. (2020) reported that jute mallow prevents gut dysbiosis and obesity. This vegetable also has anti-inflammatory activity, as investigated in rats (Zakaria et al., 2006). Jute mallow leaves exhibit anti-inflammatory and anti-hyperglycemic properties in rodent models for diabetic mellitus (Mokgalaboni & Phoswa, 2022). Ethanolic extract of *Corchorus olitorus* leaves in Alloxan-induced diabetic rats exhibited anti-hyperglycemic properties, and it was concluded that this vegetable can be used in the management of diabetes (Olusanya et al., 2018).

Jute mallow is a traditional leafy vegetable crop harvested in the wild in tropical and subtropical regions (van Rensburg et al, 2007), with a higher nutritional value than cabbage, spinach, and other leafy vegetable crops (Oelofse & Van Aberbake, 2012; Naimi et al., 2015). The edible leaves of jute mallow are high in provitamin A (-carotene), calcium, thiamine, niacin, folate, riboflavin, zinc, and iron (Swanepoel et al., 2018). The leaves of jute mallow play an important role in nutrition and food security, with an average of 15% dry matter, 4.8 g of protein, 259 mg of calcium, 4.5 mg of iron, 4.7 mg of vitamin A, 92 g of folates, 1.5 mg of nicotinamide, and 105 mg of ascorbic acid per 100 g of leaves. iron, riboflavin, and zinc (Tovihoudji et al., 2015).

2.2.4.2. Amaranthus

Traditionally, amaranth has been used to treat constipation, haemorrhage, wounds and as a tapeworm repellent (Gruben, 2004). Fast wound healing was probably due to the ethanolic extract, which inhibited the growth of bacteria and fungi (Paswan et al., 2020). The antioxidant capacity of Amaranthus species contributes largely to its medicinal value (Adegbola et al., 2020). This vegetable also has antioxidant, antimalarial and anti-inflammatory effects. Numerous studies have examined the pharmaceutical potential of amaranth. Methanolic extract of aerial parts of four Amaranthus species (*A dubius, A. spinosus, A. tricolor, and A. viridis*) were evaluated for variation in antioxidant, anti-inflammatory and anticancer activities (House et al., 2020). High anti-inflammatory activity was observed in *A. spinosus,* while high anticancer activity against MCF7 cells was observed in *A. dubius* (House et al., 2020). In addition, a study by Nahar et al. (2018) investigated the effects of *Amaranthus tricolor* on isoproterenol-induced oxidative stress, fibrosis, and myocardial damage in ovariectomized rats. The authors reported that the application of *A. tricolar* may protect against ISO-induced myocardial infarction in ovariectomised rats, thereby preventing inflammation, oxidative stress, and fibrosis (Nahar et al., 2018). Furthermore, the ethanolic extract of *A. spinosus* was evaluated for its wound-healing activity and antioxidant potential to promote rapid wound healing (Paswan et al., 2020). Fast wound healing was reported due to the antioxidant potential of *A. spinous* ethanolic extract, and it also inhibited the growth of both bacterial and fungal infections (Paswan et al., 2020).

Amaranthus have high nutritional value due to their high content of essential micronutrients such as b-carotene, iron, calcium, vitamin C, and folic acid. Protein, calcium, iron, vitamins A, C, and K, riboflavin (B2), niacin (B3), vitamin B6, and folate (B9) are all essential nutrients found in Amaranthus (Priya et al., 2007; Enoch et al., 2014; Ruth et al., 2021). According to previous research, Amaranthus seeds are a useful source of gluten-free protein that can be used to make a variety of snacks from around the world (Tömösközi et al., 2011). As a result, it is a promising and unique plant to be investigated for its high levels of essential nutrients, as it is a rich source of micronutrients (essential vitamins and minerals), which have been studied as essential to optimal wellbeing. In addition, amaranthus contains amino acids such as lysine, arginine, histidine, leucine, cysteine, phenylalanine, isoleucine, valine, threonine, and methionine (Reyad-ul-Ferdous et al., 2015). Amaranthus is high in potassium, calcium, iron, zinc, magnesium, and a variety of carotenes and vitamins A-C, all of which have been linked to improved health (Jimoh et al., 2018). It was rated higher in nutritional composition than common vegetables such as cabbage and spinach (Ramdwar et al., 2017). According to Peter et al. (2017), Amaranthus grain has been noted for its high protein content, complete essential amino acids, and higher lysine content than other grains. Furthermore, it is known for its high-quality starch, oil, fibre, vitamins (A, K, B6, C, E, and B), and essential minerals such as calcium and iron. It also has advantages as a food supplement because it is gluten-free and high in quality protein and unsaturated. It is also a rich source of fibre and an alternative natural source of squalene (a triterpene), a superior antioxidant with wide biological efficacy against cancer.

2.2.4.3. Spider plant

The parts utilised for medicinal purposes include roots, stems, and whole leaves (Onyango et al., 2013). Some of the traditional uses of the spider plant include relieving constipation, conjunctivitis, pains, epileptic fits, ear infection, cure scurvy and marasmus, improve eyesight, provide energy, reduce length of labour (Chweya and Mnvanza, 1997), and to treat anaemia, rheumatism, and chest pain (Gruben, 2004). Spider plant also contains micronutrients and phytochemicals that are associated with antioxidants, antimalaria and anti- microbial properties (Onyango et al., 2013). Spider plant leaves have been reported to have anti-inflammatory properties (Chweya & Mnzava, 1997; Onyango et al., 2013).
Several studies have used animals to evaluate the medicinal properties of the spider plant. Leaf extract of spider plant has significant anti-arthritic activity, as evidenced by reduced paw volume in rats (Narendhirakannan et al., 2005). Narendhirakannan et al. (2007) reported that the spider plant has anti-arthritic properties, and this may be due to the presence of phytochemicals such as triterpenes, tannins, anthroquinones, flavonoids, saponins, steroids, resins, lectins, glycosides, sugars, and phenolic compounds. Spider plant is an important indigenous leafy vegetable that is particularly important in the

diets of many rural communities in Africa, including South Africa (Muchuweti et al., 2009; Thovhogi et al., 2021). The plant is said to be high in minerals, proteins, vitamins, flavonoids, antioxidants, and a variety of other compounds, and can help reduce micronutrient deficiencies (Mashamaite et al., 2022). Mineral elements such as calcium, iron, magnesium, and zinc, copper, potassium, magnesium, manganese, phosphorus, and sodium have been found in high concentrations on spider plant leaves (Jinazali et al., 2017; Jiménez-Aguilar & Grusak, 2015; Omondi et al., 2017; Gowele et al., 2019; Thovhogi et al., 2021). Its leaves are extremely nutritious and are primarily consumed by humans.

2.2.4.4. Nightshade

Solanum plants contain various phytochemicals, including tannins, flavonoids, alkaloids, glycosides, steroids, and terpenoids, which are used in medicine and food as functional foods or dietary supplements (Neacsu et al., 2015; Kumar et al., 2016; Piana et al., 2016). These compounds vary by species, plant part, and extraction method (Kumar et al., 2016). Nightshade is a rich source of nutrients such as thiamine, ascorbic acid, iron, calcium, zinc, protein, and dietary fiber (Kirigia et al., 2019; Ontita et al., 2017; Ronoh et al., 2017; Yuan et al., 2018). The leaves of Solanum nigrum contain more protein, fiber, and total ash than the berries of the same species (Sangija et al., 2021). However, the berries are higher in fat and carbohydrates. Furthermore, the leaves of S. nigrum contain more vitamins A, C, and B9 than the berries; the berries, in turn, contain more vitamin B1. African night shade is one of the known nutrient-rich African leafy vegetables used to promote food and nutrition security in Sub-Saharan Africa (SSA) (Yang & Ojiewo, 2013). Micronutrients such as carotene, vitamins C and E, minerals (iron, calcium, and zinc), and dietary fibre are abundant in African nightshade. The leaves also contain nutrients than the berries (Sangija et al., 2021).

2.2.4.5. Cucurbita

Cucurbita have been used for the treatment of nephritis, tuberculosis, internal helminthiasis, and parasitic infections (Krimer-Malesevic, 2020). Pumpkin peels and flesh contain essential minerals and phytochemicals, which aid in anti-ageing and immune system function (Hussain et al., 2021). Moreover, the seeds are rich in zinc and are being studied for their potential use in low-cost powders for functional ingredients and nutraceuticals in food and pharmaceutical industries (Hussain et al., 2021). Cucurbits are well-known multifunctional ingredients in the diet, rich in nutrients, and have opened new vistas for scientists over the past years (Batool et al., 2022). All the listed parts of the pumpkin (seeds, fruits, and flowers) are edible and contain nutrients that give them specific health-promoting properties (Gbemenou & Ezin, 2022; Nakazibwe et al., 2019). The fruit of pumpkin including the flesh, seed, and peel are a rich source of primary and secondary metabolites, including proteins, carbohydrates, monounsaturated fatty acids, polyunsaturated fatty acids, carotenoids, tocopherols, tryptophan, delta-7-sterols, and many other phytochemicals (Batool et al., 2022). It is high in dietary fibre, antioxidants, bioactive compounds, and vitamins and minerals (Dhiman et al., 2009). Pumpkin seeds contain a high concentration of protein and oil. Pumpkin seed is an excellent dietary source of protein, oil, and some essential micronutrients (Peng et al., 2021). In addition to carbohydrates, proteins, and other common nutrients, pumpkin seeds also contain vitamins, carotenoids, squalene, phytosterols, cucurbitacin, and phenolic compounds (Wang et al., 2017). The pumpkin seed also contains substantial amounts of macro and micro minerals such as phosphorus, magnesium, potassium, calcium, zinc, iron and sodium (El-Adawy et al., 2001). Younis et al. (2000) also discovered that *Curcubita pepo* seeds are rich in oil, with the oil containing four dominant fatty acids, which are palmitic, stearic, oleic, and linoleic. The nutritional potential of edible flowers is exceedingly high in pumpkin production (Bieżanowska-Kopeć et al., 2022).

2.2.4.6. Balsam pear

This review will concentrate on the three edible species of Momordica, *Momordica charantia L*. (Bitter melon), *Momordica foetida* (bitter cucumber) and *Momordica balsamina* L (African pumpkin). These vegetables have been used in traditional medicine to treat malaria fevers, diabetes (Ramalhete et al., 2022). The parts used for medicinal purposes include the whole plant, leaves, roots, and fruits. These vegetables extract have been reported to have antidiabetic, anti-microbial, anthelmintic bioactivity, abortifacient, anti-bacterial, anti-viral and have chemo preventative functions (Muronga et al., 2021). *Momordica spp*. Possess medicinal values such as treatment of gastrointestinal disease, cancer, ageing, neurological disease, diabetes, cardiovascular disease and hypertension (Muronga et al., 2021; Omokhua-Uyi & Van Staden, 2020). *Mormodica balsamina* L. has been used in traditional medicine to treat malaria, fever, and diabetes (Ramalhete et al., 2022). Medicinally *Momordica balsamina* L. leaves, roots, fruits and seeds are used as decoction, infusion, poultice or as herbal tea. Two different extracts of bitter melon showed an effect on insulin resistance in rats fed a high fructose diet (Shih et al., 2009).

Balsma pear is among the most nutritionally dense and abundant medicinal vegetables worldwide (Islam et al., 2011). It contains many phytonutrients, including fibre, minerals, vitamins, and antioxidants (Klomann et al., 2010). Ali et al. (2008) and Sorifa (2018) also confirmed that bitter gourd is an important source of carbohydrates, proteins, vitamins, minerals, and other nutrients in the human diet, which are essential for good health (Krishnendu & Nandini, 2016). It is high in dietary fibre and high in vitamins B1, B2, B3, C, magnesium, folic acid, zinc, phosphorus, and manganese (Keding & Krawinkel, 2006). It has twice the beta-carotene of broccoli, twice the calcium of spinach, and twice the potassium of a banana. It also contains glutmine, asparagines, glycine, lysine, alanine, leucine, valine, arginine, proline, serine, isoleucine, phenylalanine, tryptophan, histidine, threonine, and methionine (Islam et al., 2011). Bitter gourd has been reported to have a higher nutritional value than cucumber, zucchini, and squash (Krawinkel & Keding, 2006; Singla et al., 2023). The fruit is primarily rich in nutrients such as vitamins A and C, tocopherols, thiamine, riboflavin, niacin, and folic acid. The tender vine tips are high in Vitamin A and a useful source of protein, thiamin, and Vitamin C.

2.2.4.7. Cowpeas

Cowpea is used in medicine, fodder, feed, and food (Enyiukwu et al., 2018). Its root is used as an antidote for snakebite, and its porridge treats chest pain, epilepsy, dysmenorrhea, and fever (FAO, 2016; Enyiukwu et al., 2018). Pulses and pulse-derived vegetables are used as tonics, stimulants, aphrodisiacs, and anthelmintics (Campos-Vega et al., 2010). Cowpea is one of the African indigenous vegetables that has been suggested as a potential solution to food and nutrition insecurity in Sub-Saharan Africa (SSA) (Owade et al., 2020). The vegetable is high in micronutrients, proteins, and amino acids, as well as iron and vitamin A, both of which are deficient in SSA. The leaves have been used to make food and feed. They contain a high concentration of micronutrients, nutraceuticals, and antioxidants. The leaves contain antioxidants such as alpha tocopherols, flavonoids, lycopene, and anticancer agents (Shetty et al., 2013). This vegetable contains important nutrients such as vitamins and minerals that, when used properly, can improve the nutritional status of individuals and households (Okonya & Maass, 2014). Cowpea leaves have a high nutritional value, making them ideal for efforts to reduce food and nutrition insecurity. Seeds are a reliable source of amino acids, including tyrosine, tryptophan, lysine, histidine, phenylalanine, and cysteine (Korant et al., 2023). Carotene, thiamin, riboflavin, niacin, vitamin A, and folic acid are also found in tiny amounts in cowpea seeds.

2.2.4.8. Okra

In ethnomedicine, okra leaves, pods, flowers, roots and seeds are used (Roy et al., 2014). Okra pods, fruit and mucilage contain certain bioactive compounds with medicinal properties (Elkhalifa et al., 2021). Some of the medicinal uses of okra include antispasmodic, demulcent, diaphoretic, diuretic, emollient, and stimulant (Kumar et al., 2013; Roy et al., 2014). It can also be used to treat syphilis, wounds, cuts and boils (Kumar et al., 2013). Okra contains high levels of phenolic compounds with biological properties and strong antioxidant activity. Some of the potential health benefits of okra include the treatment of diseases such as type 2 diabetes, digestive diseases, some cancers, and cardiovascular disease; an antifatigue effect; liver detoxification; antibacterial and chemo preventive activities (Elkhalifa et al., 2021; Gemede et al., 2014). According to Khatun et al. (2011), viscous soluble fibre from okra in fasting rats significantly reduced intestinal glucose absorption.

2.2.4.9. Spindle pod

Extracts of Cleome species are used to treat inflammation, wounds, fever, discomfort, depression, and diarrhoea (Singh et al., 2018). *Cleome monophylla* is utilised for its medicinal properties for the treatment of ulcers, boils, wounds, cough, headache, swellings, acceleration of maturation, ear discharges, fever, anthelmintic properties, as well as for its rubefacient and vesicant effects (Grubben, 2004). It is also used to treat to treat retained placenta (Tugume et al., 2016). *Cleome monophylla* has higher mineral content (Ca, P, Na, Zn, Mg, Mn, and Fe) than regularly consumed commercial vegetables (Sivakumar et al., 2018). Extracts of Cleome species are used for the treatment of inflammation, wounds, fever, discomfort, depression, and diarrhea (Singh et al., 2018). *Cleome monophylla* is used for its medicinal properties for the treatment of ulcers, boils, wounds, cough, headache, swellings, acceleration of maturation, ear discharges, fever, anthelmintic properties, as well as for its rubefacient and vesicant effects (Grubben, 2004). It is also used to treat to treat retained placenta (Tugume et al., 2016).

2.2.4.10. Blackjack

Blackjack is an indigenous leafy vegetable that has been used in traditional medicine globally including South Africa (Takaidza et al., 2023; Authur et al., 2012). This vegetable has been used to treat several diseases in many African countries. Blackjack is used as a blood clotting agent, for headache, ear infection, kidney problems, flatulence, stomach/mouth ulcers, arthritis/ malaria, poison antidote, ease child delivery, relieve pain from hernia and diarrhea (Authur et al., 2012). According to Bartolome et al. (2013) traditionally blackjack has been reported to treat over 40 diseases. Several studies have been conducted to validate the traditional use of blackjack in medicine. Njume et al. (2016) reported that blackjack has antimicrobial activity, and this may be due to one or more of the 6 secondary metabolites (tannins, saponins, alkaloids, cardiac glycosides, steroids and flavonoids) detected in the extract and concluded that the results provide a scientific basis for the use of blackjack in traditional medicine. Furthermore, Bartolome et al. (2013) reported that the primary bioactive compounds in blackjack (Polyynes, flavonoids, phenylpropanoids, fatty acids, and phenolics) were efficient in the treatment of tumours, inflammation/immune modulation, diabetes, viruses, microbes, protozoans, gastrointestinal diseases, hypertension, and cardiovascular diseases. Ajanaku et al. (2018) reported that blackjack has the potential to treat tuberculosis due to its antimicrobial and anti-tubercular properties, and it can also be used in drug formulation. Furthermore, it was reported that blackjack is also useful in the treatment of heart failure due to the presence of cardiotonic glycosides (Ajanaku et al., 2018). Blackjack has been documented for its use in the management of diabetes, hypertension, and obesity throughout many continents worldwide (Bartolome et al., 2013; Kuo et al., 2021).

2.2.5. Water requirements for traditional leafy vegetables

Water availability in the soil is one of the most important requirements for successful vegetable production. Adequate moisture is necessary for good crop establishment, growth, yields, and quality. However, crops differ in their water requirements. The amount of water required by a crop differs during its growing period, partly due to variation in weather conditions, irrigation methods, crop canopy, and agronomic practices. Adequate water is essential for the good germination of all crops. Crop water requirement, also known as evapotranspiration, is the quantity of water lost from the plant through transpiration plus the amount of water lost from the soil by surface evaporation. Doorenbos and Kassam

(1977) defined crop water requirement as the quantity of water required by a crop or mixed population of crops during a given period of its normal growth under field conditions. Water scarcity is a major threat to food and nutritional security, not only in South Africa but across the African continent. Therefore, adaptation to water scarcity is a key focus of climate change adaptation and mitigation programs in South Africa. Among various adaptation mechanisms, the selection and promotion of traditional leafy vegetables with low water requirements for smallholder farmers and home gardens can improve a community's nutritional and health status. The aim of reducing water use and enhancing food and nutritional security could be achieved through the selection and promotion of traditional leafy vegetables with low water requirements for smallholder farmers and home gardens.

Although traditional leafy vegetables have been documented to address challenges such as water scarcity, there is limited information on their yield responses to water. Few studies have examined the nutritional yield of these traditional leafy vegetables under water-limited conditions (Masinde et al., 2006; Jansen van Rensburg et al., 2007; Luoh, 2014). Although it is possible to produce indigenous vegetables under limited water conditions, some studies showed that an adequate amount of water is needed to achieve marketable yields (Masinde et al., 2006; Jansen van Rensburg et al., 2007; Luoh, 2014). Recent studies on the nutritional water productivity of Amaranthus and *Cleome gynandra* reported yield reductions under water stress (Luoh, 2014). The study found that both fresh and dry stem and leaf weights decreased significantly in all crop groups under the water-deficient treatment. Traditional leafy vegetables were also reported to yield comparably to Beta vulgaris under similar conditions (Luoh, 2014). Oelofse & van Averbeke (2012) studied and identified differences among the water requirements of the eight indigenous leafy vegetables. TLV species for optimal production were identified. The water requirement over the full growing season was 340 mm for pumpkin, tsamma melon and cowpeas, 360 mm for pigweed, 368 mm for Jew's mallow, 381 mm for nightshade, 382 mm for non-heading Chinese cabbage and 463 mm for spider flower (Table 2). The study concluded that all eight traditional leafy vegetables were sensitive to water stress, indicating that the production of these crops depends on the availability of sufficient water. The fact that traditional leafy vegetables are usually grown in harsh environments does not necessarily mean they require less water to achieve maximum production. The results of Oelofse & van Averbeke (2012) indicated that all eight traditional leafy vegetables were sensitive to water stress. In general, the study found that irrigating traditional leafy vegetables to field capacity (100% FC) resulted in higher yields and better-quality leaves than other treatments. Subjecting traditional leafy vegetables to 25% FC did not yield well and is therefore not recommended. These findings indicate that the production of traditional leafy vegetables depends on sufficient water availability. Although traditional leafy vegetables have been documented to address challenges such as water scarcity, further research is needed to establish the water requirements of other indigenous vegetables consumed in the Vhembe district.

Table 2. Seasonal actual crop water uses for the selected traditional leafy vegetables

Indigenous vegetable	Seasonal crop water use (ETc mm)
Night shade	381
Pumpkin	340
Chinese cabbage	382
Tsamma melon	340
Jew’s mallow	368
Cowpea	340
Pigweed	360
Spider flower	463

2.3. CONCLUSION

From this review, it can be concluded that encouraging the cultivation and consumption of traditional leafy vegetables can help address challenges such as food insecurity, hunger, and malnutrition. Several studies have reiterated the importance of consuming traditional leaf vegetables on the health of humans. Many indigenous vegetables were found to contain substances that can help cure some diseases. If properly executed, the commercialisation of indigenous vegetables can increase income for smallholder farmers, create jobs, and reduce the unemployment rate. Promoting the cultivation and consumption of indigenous vegetables can provide an opportunity to address some of the Sustainable Development Goals (SDGs 1, 2, and 3) set by the United Nations General Assembly in 2015. Although a lot of work has been reported on traditional leafy vegetables in South Africa, little has been done on cultivation techniques, largely due to a lack of knowledge, in-depth research, and policies that encourage the cultivation of indigenous vegetables.

CHAPTER 3: IDENTIFICATION OF TRADITIONAL LEAFY VEGETABLES, THEIR HEALTH BENEFITS AND NUTRITIOnaL VALUES IN VHEMBE DISTRICT OF LIMPOPO PROVINCE, SOUTH AFRICA

3.1. INTRODUTION

Traditional leafy vegetables (TLVs) play a significant role in reducing food insecurity, combating malnutrition, and alleviating poverty, particularly in Africa. TLVs are a source of fibre, proteins, minerals and antioxidants. However, consumption of traditional leafy vegetables is increasing, but at a snail's pace. This has been associated with several factors, such as a lack of quality planting materials, insufficient agricultural resources, stigmatisation, and excessive production of exotic vegetables (Jansen van Rensburg et al., 2007). Furthermore, socioeconomic factors, including location, income, literacy level, and land size, also determine how people consume traditional leaf vegetables. Traditional leafy vegetables grow well in harsh environments with minimum inputs (Ekesa et al., 2015). Traditional leafy greens can be harvested in a truly fleeting time since they grow and mature quickly (Zamede, 1997). Traditional leafy vegetables such as blackjack, African nightshade, spider plant, and bitter gourd serve as a source of nutrients, carbohydrates, and proteins (Ekesa et al., 2015). Regardless of its significant contribution to food security, combating malnutrition, reducing unemployment and alleviating poverty for decades in South Africa, its consumption rate has been reported to be dwindling, partly due to the high cultivation of exotic vegetables, lack of proper research, lack of government intervention, wrong perceptions, and poor marketing. Socioeconomic factors, including location, income, literacy level, land size, household size, access to markets, and access to credit, were identified as drivers of traditional leafy vegetable consumption (Jansen van Rensburg et al., 2007). The project aimed to identify and document native knowledge of traditional leafy vegetables commonly consumed in the Vhembe district. The specific objectives of the survey were to establish the diverse types of traditional leafy vegetables grown by rural communities and their nutritional values; identify traditional vegetables with medicinal value; and identify factors that influence people's decision to consume, produce, and sell traditional vegetables in Vhembe district.

3.2. METHODOLOGY

This section describes the characteristics of the study location and the procedures used to collect and analyse the information. The characteristics of the study area were considered since they affect the cultivation and consumption of traditional leafy vegetables. This section describes the survey process, questionnaire formulation, and administration, which were used to collect information from participants about their native knowledge of the consumption, production, and sale of traditional leafy vegetables.

3.2.1. Characteristics of the study area

The study was conducted in Vhembe District Municipality (VDM) of the Limpopo Province (Figure 12). The district code is DC34. The Vhembe District Municipality shares borders with Zimbabwe and Botswana in the north-west and Mozambique in the south-east through the Kruger National Park. It comprises four local municipalities: Musina, Thulamela, Makhado, and Collins Chabane (Figure 13). The district has a land size of 25 597 square kilometres (Table 3) and has four towns, namely, Makhado, Malamulele, Musina and Thohoyandou.

Table 3. Characteristics of the study area

Municipality	Area		Population		Number of households	
	(km^2)	(%)	No:	(%)	No:	**(%)**
Thulamela	2 642	10.32	575 929	34.84	142 527	**32.62**
Makhado	7 605	29.71	502 452	30.39	140 338	**32.12**
Collin chabane	5 003	19.55	443 798	26.85	108 160	**24.75**
Musina	10 347	40.42	130 899	7.92	45 934	**10.51**
VDM	**25 597**	**100**	**1 653 078**	**100**	**436 959**	**100**

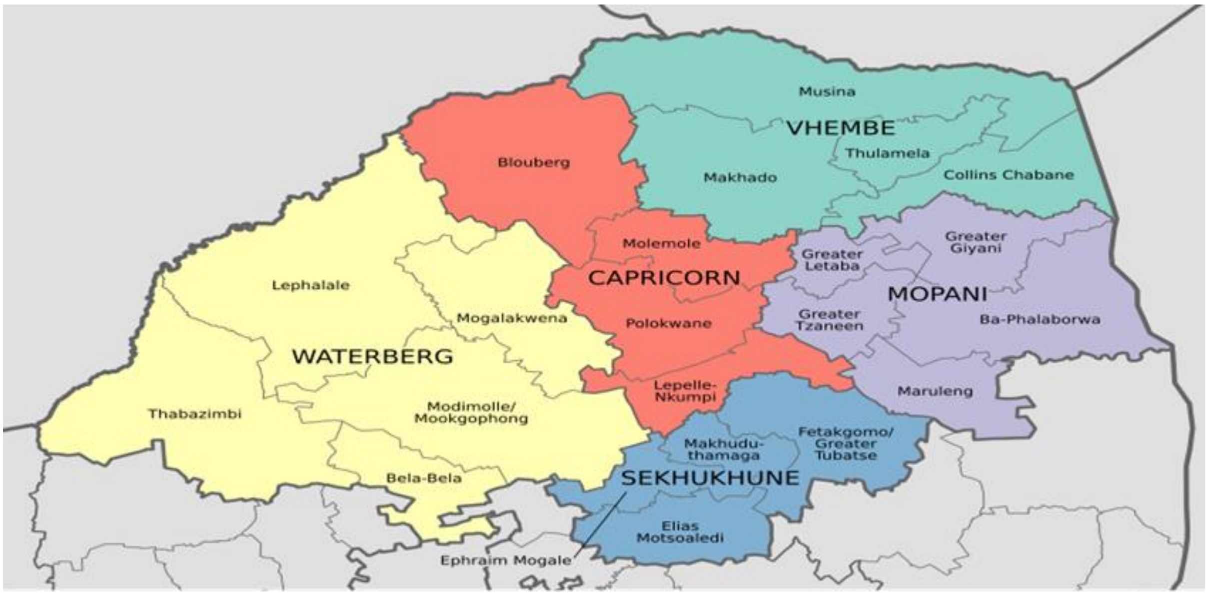

Figure 12. A map showing five districts within Limpopo Province.

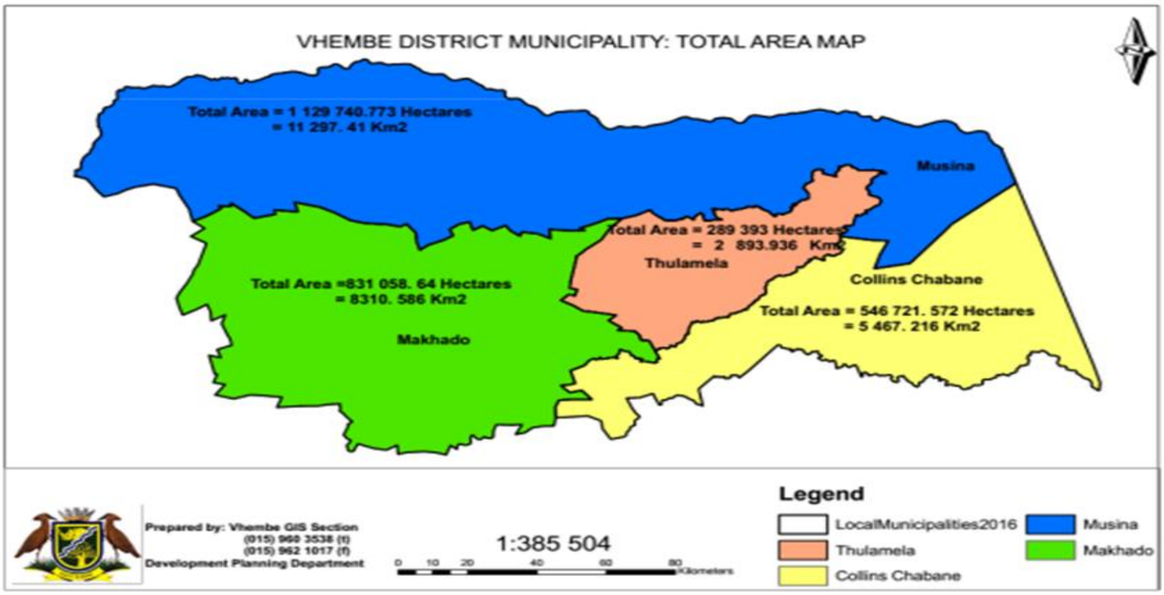

Figure 13. Four local municipalities were used for the survey

The Vhembe district is characterised by a wet and hot summer season and a cold winter season. The area receives heavy rains from mid-November to late February (680 mm). In January, the area experiences a maximum temperature of 29.9 ºC, while in July, the minimum temperature drops to 8.5 ºC (Figure 14). A long-term (10-year) summary of climatic parameters within the VDM is shown in Table 4. The average annual evapotranspiration is 81.3 mm. In March and April, the study area experiences high relative humidity of 93.6% and 93.3%, respectively, with lower relative humidity in July (31.7%) and August (34.4%). Vhembe district falls within the Savanna biome or Bushveld, which covers about 97.65 % of the district, followed by the small portion of Azonal Vegetation (1.49 %), Forests (0. 65%) and Grassland (0.22%), respectively

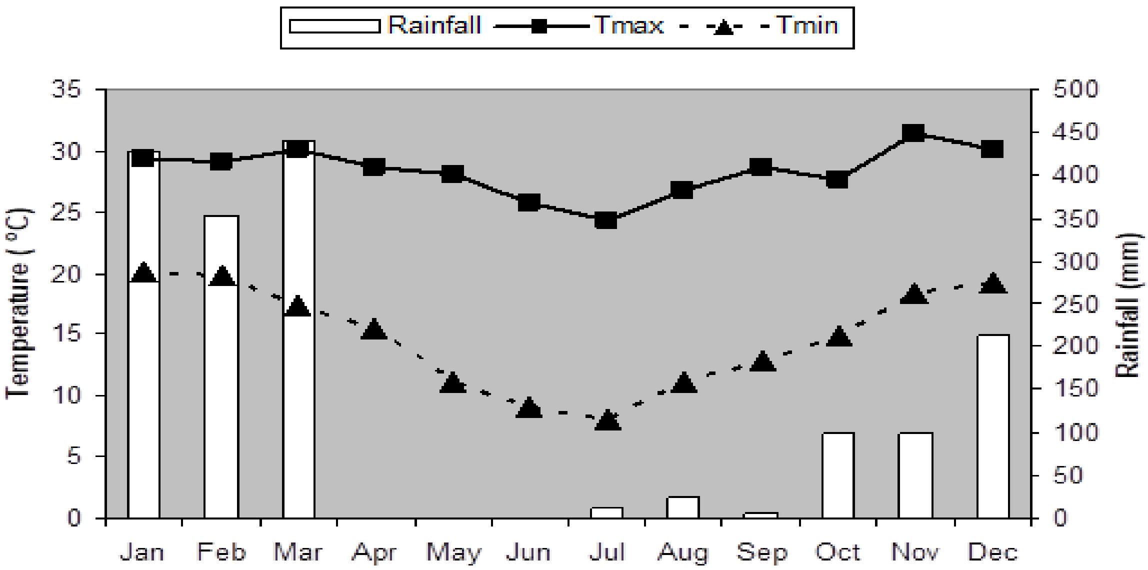

Figure 14. Mean monthly rainfall and temperature (10 year) for Vhembe district

Table 4. Mean monthly data for climate parameters in Vhembe district

Weather	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Evap (mm)	92.2	75.4	92.4	73.9	74.5	60.9	68.9	70.5	89.8	81.2	97.5	98.7
MaxRH (%)	93.3	93.6	93.3	92.9	91.6	90.3	88.5	88.3	85.1	88.0	86.6	91.5
MinRH (%)	57.6	57.5	46.6	46.2	32.8	33.6	31.7	34.4	32.3	44.2	41.4	51.4

Evap= evapotranspiration; MaxRH= Maximum Relative Humidity; MinRH= Maximum Relative Humidity

3.2.2. The survey

The survey was conducted in 4 municipalities within the district viz: Makhado, Musina, Collins Chabane and Thulamela (Figure 13).

3.2.2.1. Design and pre-testing of the questionnaire

Data from the participants were collected using a structured questionnaire. The questionnaire comprises four sections: demography, consumption, production, and sale of traditional leafy vegetables (Appendix 2). The questionnaire was sent to various stakeholders for their input before being sent to the participants. Questionnaires were distributed to 10 randomly selected people to pre-test the questionnaire and ensure the questions were clear and understandable.

3.2.2.2. Ethical consideration

The survey was conducted in accordance with ethical data-collection guidelines. Permission to conduct the survey was obtained from the respondents by informing them of the survey's aim and objectives, as well as their role as respondents. Participants were informed that they had the right to decline to answer specific questions if they found them uncomfortable. The questionnaire did not contain any identifying information about the respondents, and all the information was kept confidential. Ethical clearance certificates were provided by the ethics faculty committee of the University of Venda and by the Vhembe Subtropical Farmers and Nursery Association.

3.2.2.3. Sampling procedure

The survey focused on people who consume, produce, and sell traditional leafy vegetables in the Vhembe district. Survey planning meetings were held with all stakeholders from each municipality before data collection. In each local municipality, 49 participants were selected using simple random sampling. The selection was based on every third person we met. The purpose was to avoid bias and ensure that all people had an equal opportunity to be selected.

3.2.2.4. Data coding and analysis

Questionnaires were administered to the selected participants for completion independently. Respondents who could not read English were assisted by the survey team members and agricultural advisors. However, survey team members and agricultural advisors assisted illiterate participants in completing the questionnaire. The collected information was screened, coded, and captured in a personal computer. Frequencies, standard deviations, percentages, and cross-tabulations were calculated using the Statistical Package for the Social Sciences (SPSS, 2004) and used to interpret the results. The differences between the observed data and the expected distribution were tested at the 5% level of significance using a chi-square (χ2) test.

3.3. RESULTS

3.3.1. Characteristics of the participants

Of the 196 participants who participated in the survey, 52% were males and 48% were females (Figure 15). This distribution was consistent with the trend in the Vhembe district, where vast areas of the farming lands are owned by men (Statistics South Africa, 2003). Thulamela, Collins Chabane, and Musina local municipalities had more men, while Makhado local municipality had fewer. There was a higher proportion of youth (16–35 years), followed by those who are between 36 and 55 years. However, Musina had a higher proportion of elders (>65 years) than other municipalities (Figure 16).

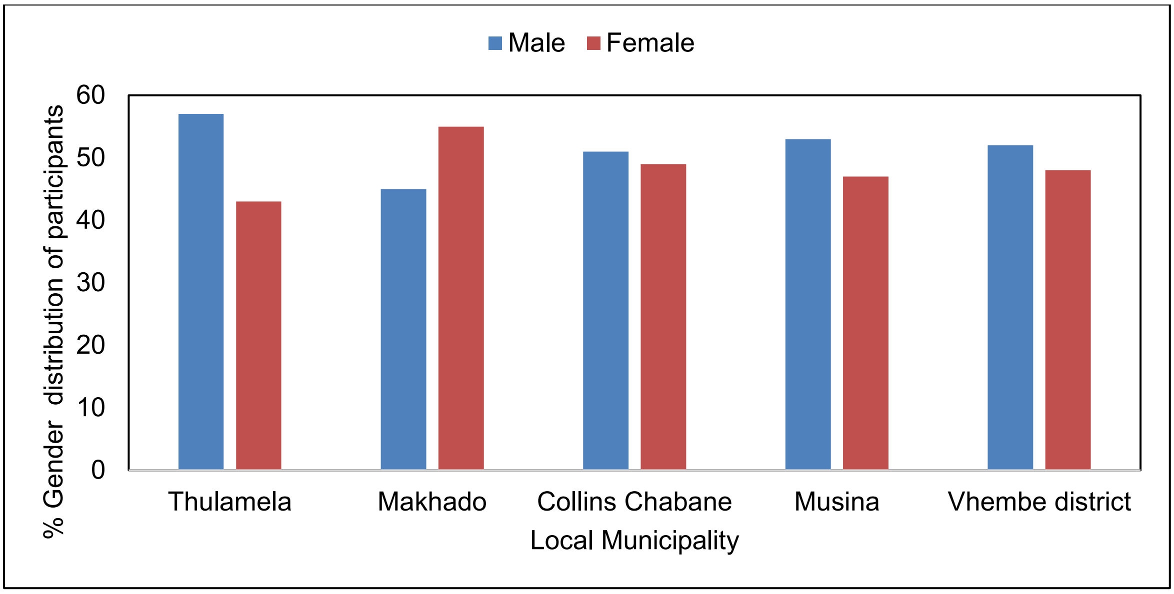

Figure 15. Gender distribution of the participants within each municipality

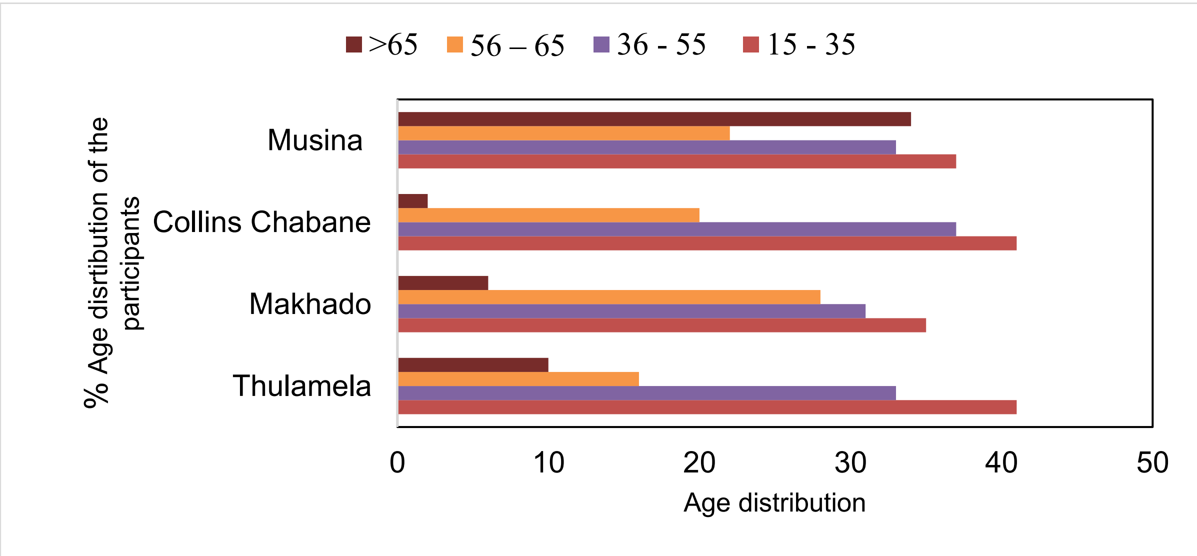

Figure 16: Age distribution of the participants within each local municipality

The educational levels of the participants within the study area are shown in Figure 17. The proportion of participants with basic education was higher in all the four local municipalities followed by those with diplomas in various fields of study, however Musina takes the lead. The marital status of the participants is shown in Figure 18. Except for Musina municipality, the proportion of the participants who are single is higher in Thulamela, Makhado and Collins Chabane.

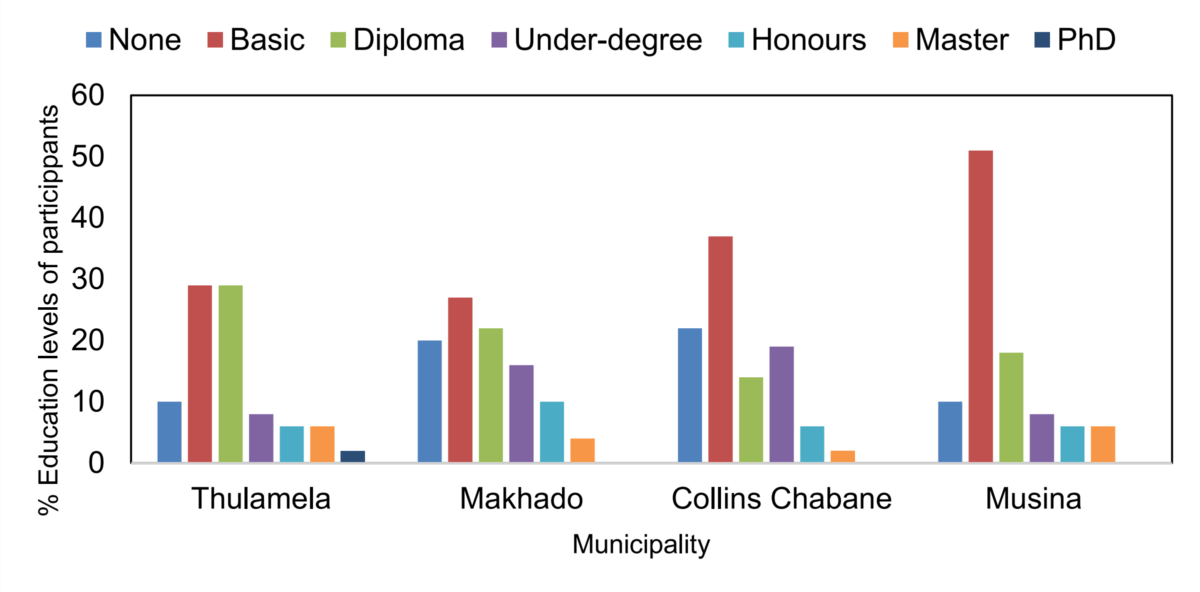

Figure 17: Level of education of the respondents within each municipality

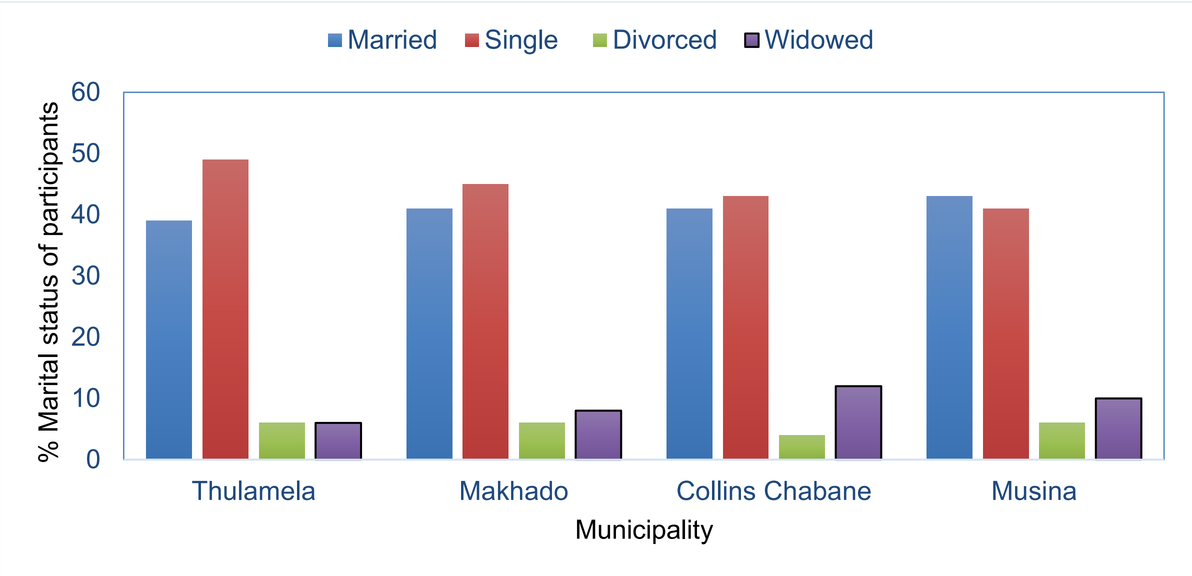

Figure 18: Marital status of the participants within each municipality

Figure 19 shows the various sources of income for the participants. The sources of income and monthly expenses have a significant effect on the consumption patterns of the participants. The major source of income across the study area was salary (47%), followed by grants (25%) and farm income (17%), respectively. Collin Chabane (63%) and Makhado (59%) local municipalities have a high number of respondents who obtained their incomes from wages and salaries, as compared to Thulamela and Musina municipalities. A large number of participants (47%) spend more than R2 000 per month (Figure 20). Only 8% of participants reported monthly food expenses of less than R500.

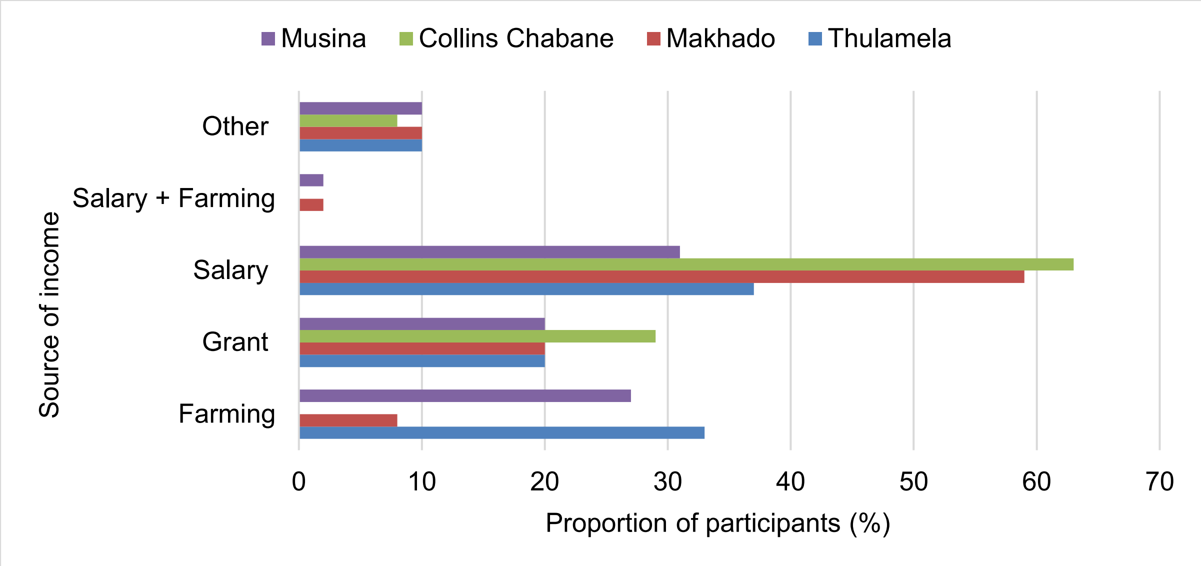

Figure 19. Sources of income for the participants within the study area

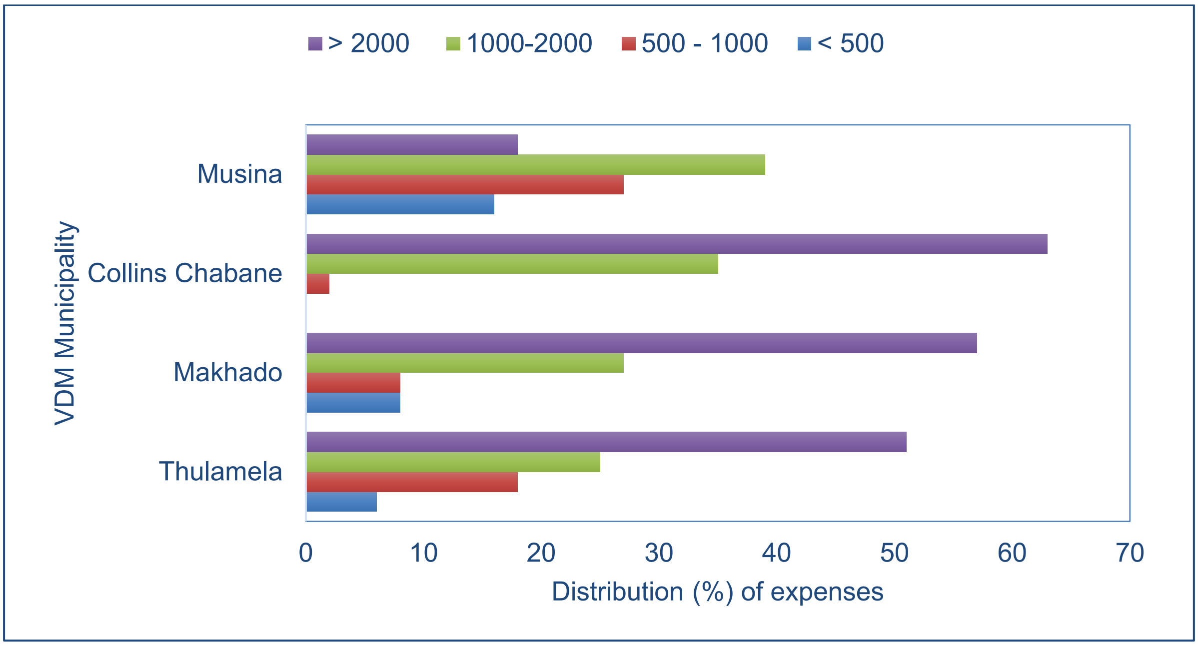

Figure 20. Distribution of monthly food expenses within the four local municipalities

The majority of participants (65%) in the Vhembe district had land of less than 1 ha, with only 35% having land of 2 ha or more (Figure 21). Thulamela had a high proportion (14%) of participants with land exceeding 5 ha. In Collins Chabane, no participant has land larger than 4 ha.

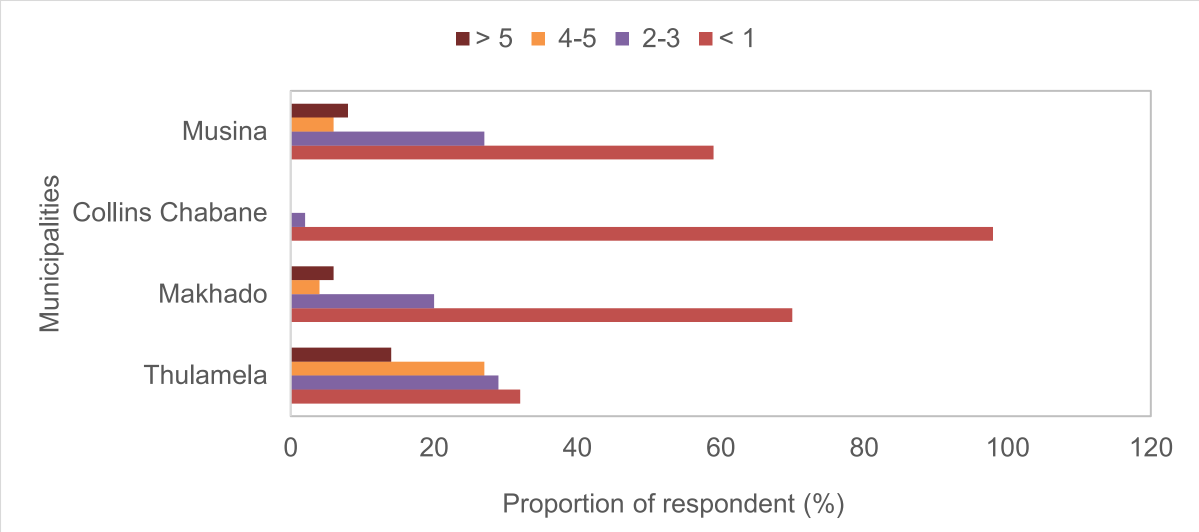

Figure 21: Distribution of land sizes within the four local municipalities

3.3.2. Identification of different traditional leafy vegetables and their roles in society

Participants were given the opportunity to indicate the category to which they belong. This is done to be able to differentiate the participants according to their category. Figure 22 illustrates the various categories that were observed during the survey. A substantial proportion of participants (35%) stated that they belong to the consumer category. In other words, they do not produce or sell traditional leafy vegetables. About 30% of participants consume, produce, and sell traditional leafy vegetables within the study area, underscoring the importance of traditional leafy vegetables in reducing poverty and curbing food insecurity. About 65% of the participants in Collins Chabane are consumers, with a few producers and sellers of traditional leafy vegetables. Participants were quizzed on the names of traditional leafy vegetables common in their areas. The list provided was compiled and ranked accordingly as reflected by the respondents (Table 5). Jute mallow was on top of the list, followed by amaranths, cowpea leaves and Okra. Stinging nettle and wild cabbage were at the bottom of the list, indicating their unpopularity within the district.

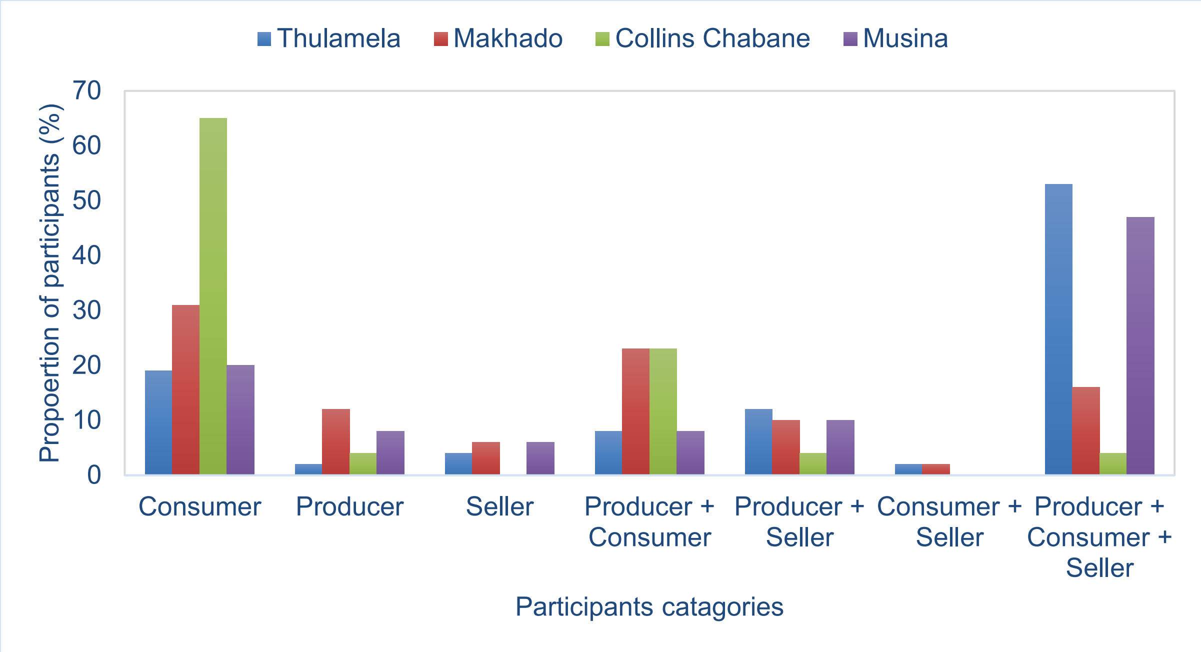

Figure 22: Categories of the respondents within each local municipality.

Table 5. Common traditional leafy vegetables within the study area

Traditional Vegetables	Frequency	Percentage (%)	Ranking
Jute mallow	31	16	1
Amaranthus	19	10	2
Cucurbita Maxima	19	10	2
Okra	19	10	2
Mustard	17	9	3
African nightshade	17	9	3
Blackjack	17	9	3
Cow pea leaves	14	7	4
Spider plant	14	7	4
Other	9	5	5
Balsam pear	7	4	6
Sweet potato leaves	5	3	7
Stinging nettle	4	2	8
Wild cabbage	4	2	8

3.3.3. The consumption of traditional leafy vegetables within the Vhembe district

Figure 23 shows the reasons participants in the study area consume traditional leafy vegetables. A large proportion of participants (53%) stated that they use traditional leafy vegetables due to their health benefits. Only 10% of the participants stated that they utilise traditional leafy vegetables because they do not have other options. About 23% of the participants understand and acknowledge the nutritional values of consuming traditional leafy vegetables. When asked about the frequency of consumption of traditional leafy vegetables, most respondents reported consuming them 2-3 times per week. Only 6% of the respondents consume traditional leafy vegetables almost every day (Table 6).

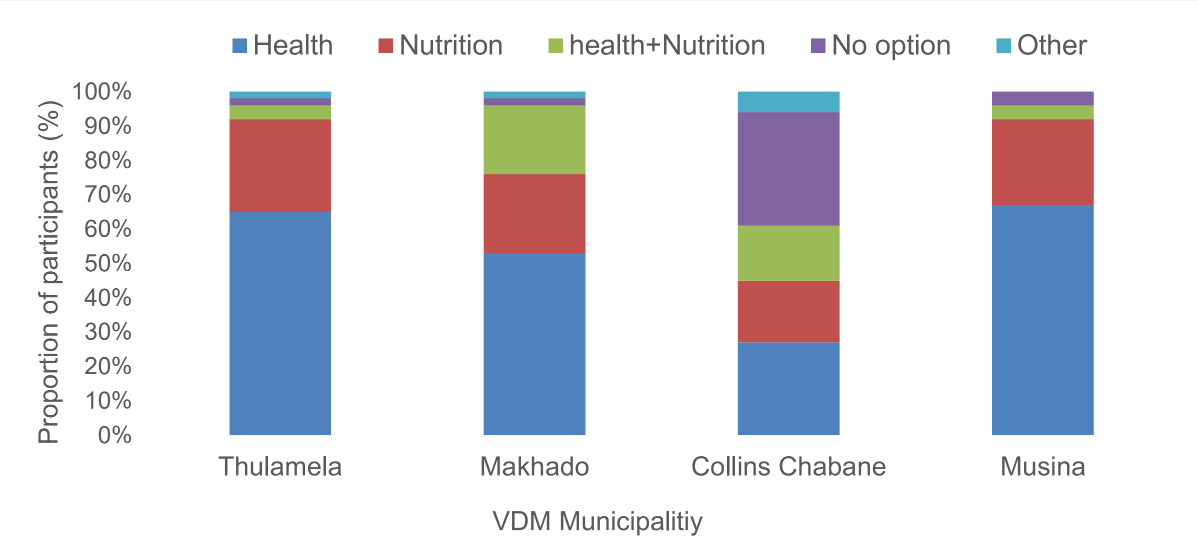

Figure 23. Reasons to consume traditional leafy vegetables by the participants within the study area.

Table 6. Traditional leafy vegetable consumption frequency for the participants within each municipality

Distribution (%)				
Municipality				
Consumption of TLVs (days/week)	Thulamela	Makhado	Collins Chabane	Musina
2-3	63 (16%)	61 (15%)	61 (15%)	53 (13%)
4-5	16 (4%)	10 (3%)	6 (2%)	24 (5%)
6-7	8 (2%)	6 (2%)	4 (1%)	6 (2%)
Once	8(2%)	10 (3%)	2 (1%)	10 (3%)
Sometimes	4 (1%)	12 (2%)	27 (6)	6 (2%)
Chi-square	131.398			
Significance	<.0001			

Chi-square (X2) significant at the 5% probability level.

The participants acknowledged that traditional leafy vegetables provide the nutrients necessary for their bodies to function well (Figure 24). They have indicated that traditional leafy vegetables provide vitamins (29%), Carbohydrates and proteins (12%), minerals (11%), and antioxidants (11%).

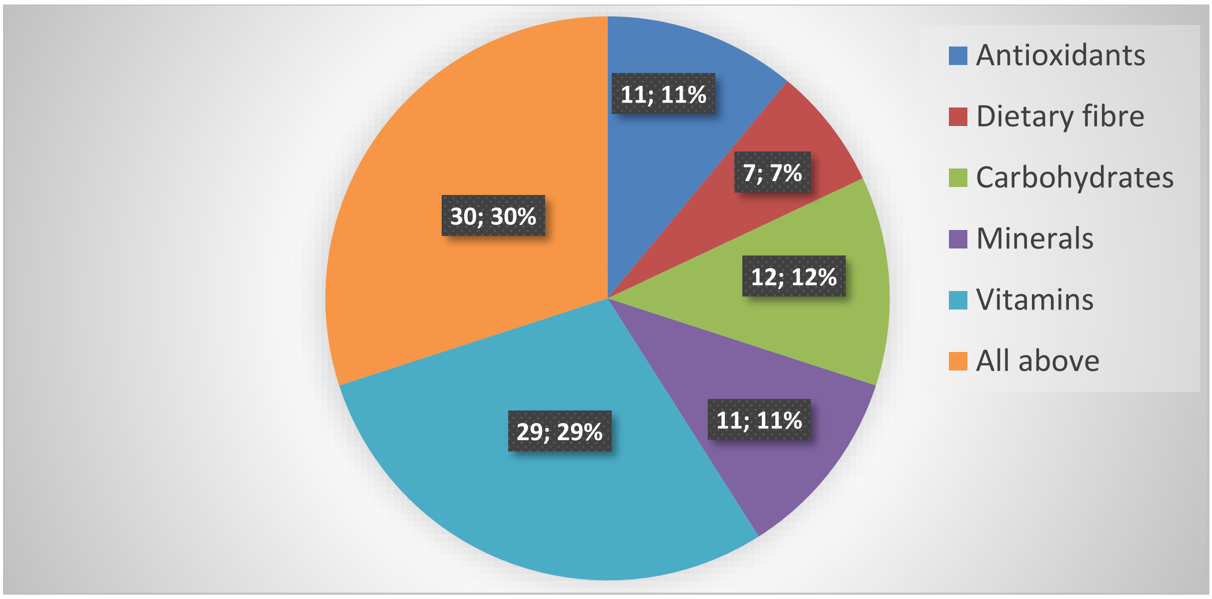

Figure 24. Nutritional benefits of consuming traditional leafy vegetables by the participants

Participants collect traditional leafy vegetables from various sources (Figure 25). The majority of the participants (65%) stipulated that they obtained traditional leafy vegetables that they consume from their home gardens, where they grow voluntarily as weeds. About 14% of the respondents buy traditional leafy vegetables from the market, while only 3% collect traditional leafy vegetables from the wild. Thulamela, Makhado, and Musina local municipalities had more participants who bought traditional leafy vegetables from the market than Collins Chabane.

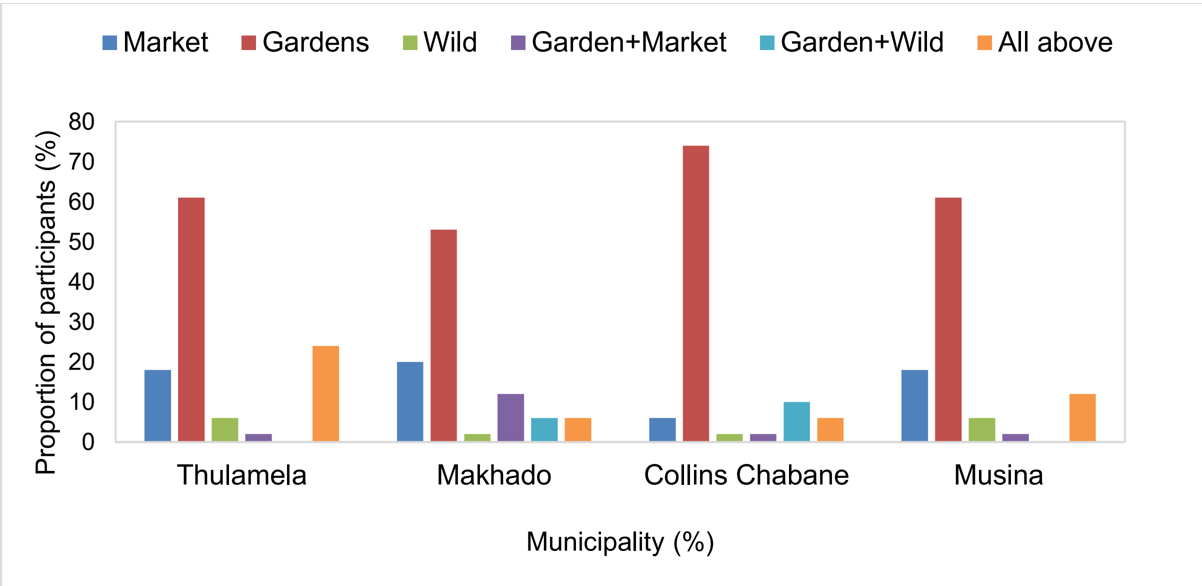

Figure 25. Sources of traditional leafy vegetables for the respondents within each local municipality

When asked whether they preserve traditional leafy vegetables, most of the participants (74%) acknowledged that they preserve some of these vegetables (Table 7). The majority of the participants (94%) in Thulamela agreed that they preserve traditional leafy vegetables, whereas 59% of the participants from Collins Chabane did not. Although participants preserve traditional leafy vegetables, the majority in Thulamela (84%) and Collins Chabane (82%) have indicated a preference for fresh traditional leafy vegetables (Table 8).

Table 7. Distribution (%) of the respondents' preference within each local municipality

Do you preserve TLV's	**Distribution (%)**			
	Municipality			
	Thulamela	Makhado	Collins Chabane	Musina
Yes	94	24	41	14
No	6	75	59	86

Table 8. Forms of traditional leafy vegetables preferred by the respondents within each municipality

	Fresh	**Dried**	**Fresh & Dried**	**Other**
Municipality	TLVs preservation method			
Thulamela	84 (21%)	2 (1%)	14 (4%)	0 (0%)
Makhado	37 (9%)	0 (0%)	61 (15%)	2(1%)
Collins Chabane	82 (20%)	2 (1%)	16 (4%)	0 (0%)
Musina	49 (12%)	0 (0%)	47 (12%)	4 (1%)
Chi-square	41.340			
Significance	<.0001			

Chi-square (X2) significant at the 5% probability level.

The respondents agreed that they preserve some traditional leafy vegetables for several reasons (Figure 26). About 49% of respondents preserved traditional leafy vegetables to consume during times of need, especially during drought periods. About 15% of the respondents preserved traditional leafy vegetables to avoid spoilage. People use different methods to preserve traditional leaf vegetables (Figure 27). A large proportion of participants (44%) stated that they preserve traditional leafy vegetables using the sun-drying technique.

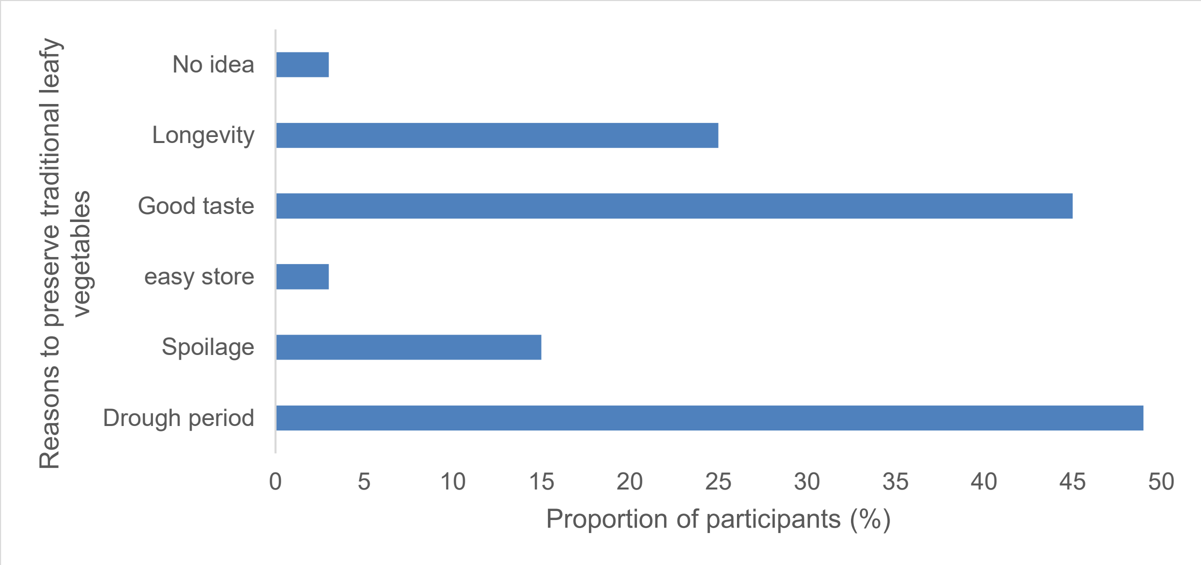

Figure 26. Reasons for preserving traditional leafy vegetables by the participants

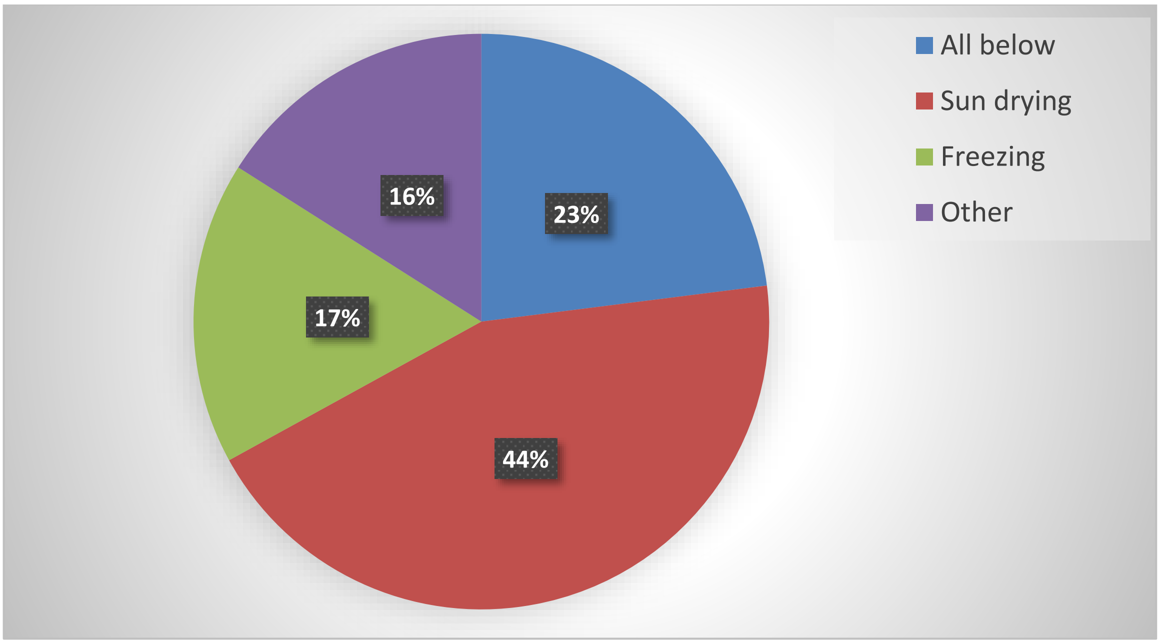

Figure 27. Methods utilised by the participants to preserve traditional leafy vegetables.

Participants listed some of the major challenges hindering the utilisation of traditional leafy vegetables in the Vhembe district. Approximately 27% of the respondents identified the lack of agricultural resources as one of the primary limiting factors (Figure 28). Some participants indicated they could produce more traditional leafy vegetables if provided with relevant resources. Preference for meat and exotic vegetables was seen by others (7%) as another factor limiting the consumption of traditional leaf vegetables in the Vhembe district.

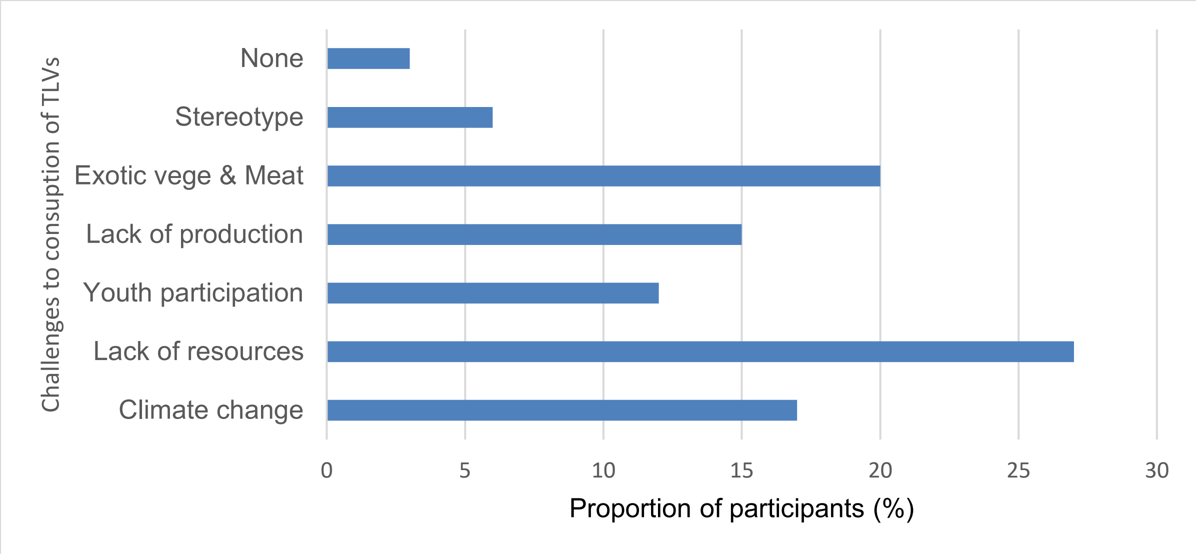

Figure 28: Challenges to the consumption of traditional leafy vegetables

3.3.4 Cultivation of traditional leafy vegetables in Vhembe district

The survey found that participants in the Vhembe district produce traditional leafy vegetables on their respective lands for various reasons (Figure 29). Approximately 41% of the respondents indicated that they cultivate traditional leafy vegetables because they are easy to grow and maintain. Traditional vegetables are known for their ability to grow under harsh environmental conditions with minimal care. The respondents were asked to provide a list of traditional leaf vegetables that they plant. About 17% of respondents indicated that they planted African nightshade, followed by Cucurbits (16%), Mustard (13%), and jute mallow (11%) (Figure 30).

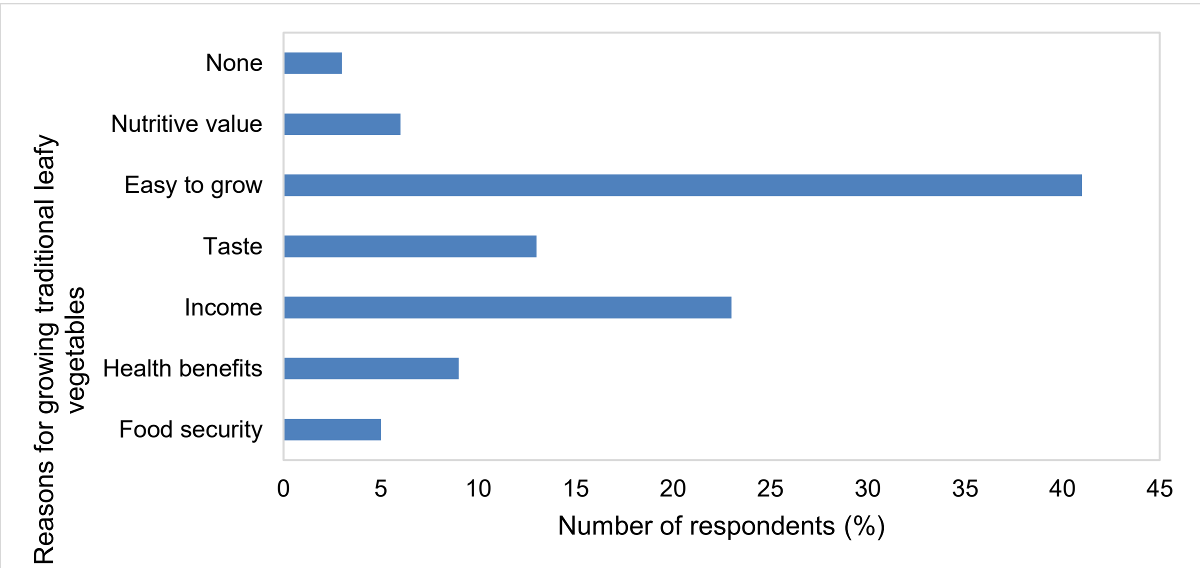

Figure 29. Reasons for producing traditional leafy vegetables

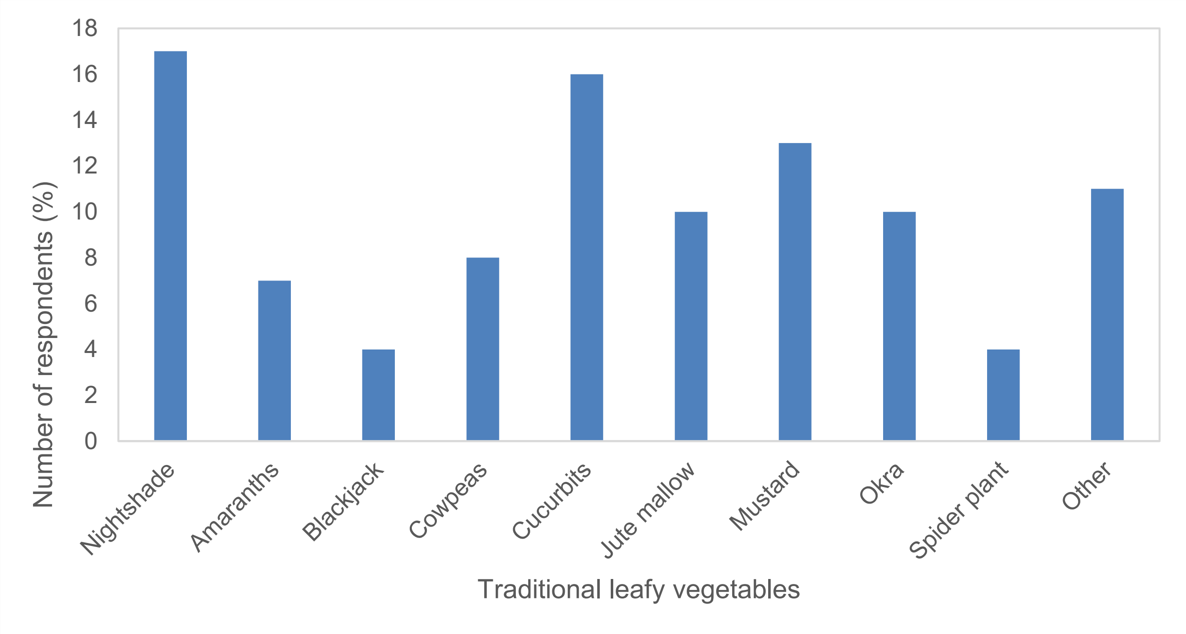

Figure 30. Cultivated traditional leafy vegetables in the study area.

The majority of participants (65%) in the Collins Chabane municipality reported receiving irrigation water from the municipality. A large proportion of participants in Thulamela (41%), Makhado (29%) and Musina (46%) obtain irrigation water from the municipality (Table 9). Respondents from the study area use different methods to apply irrigation water to their crops (Figure 31). Most respondents (52%) used the bucket system to irrigate their vegetables, followed by drip (19%) and sprinkler (12%). Although the majority of the respondents use the bucket system, most of the respondents (47%) in the Thulamela local municipality use the drip irrigation system to irrigate their traditional leafy vegetables. It is not surprising that only 3% of the respondents use a flood irrigation system. This system falls out of favour because it has so many disadvantages, such as accelerating soil erosion and nutrient mining.

Table 9. Sources of irrigation water for the respondents within each local municipality.

Distribution (%)							
Source of water for irrigation							
Municipality	**Borehole**	**Canal**	**Dam**	**Municipal water**	**River**	**Spring**	**Other**
Thulamela	33 (8%)	0 (0%)	4 (1%)	8 (2%)	41 (10%)	6 (2%)	8 (2%)
Makhado	18 (4%)	0 (0%)	0 (0%)	20 (5%)	29 (7%)	2 (1%)	31 (7%)
Collins Chabane	10 (3%)	0 (0%)	2 (1%)	65 (16%)	8 (2%)	0 (0%)	14 (4%)
Musina	20 (5%)	2 (1%)	6 (2%)	10 (3%)	39 (10%)	6 (2%)	16 (4%)
Chi-square	75.691						
Significance	<.0001						

Chi-square (X2) significant at the 5% probability level.

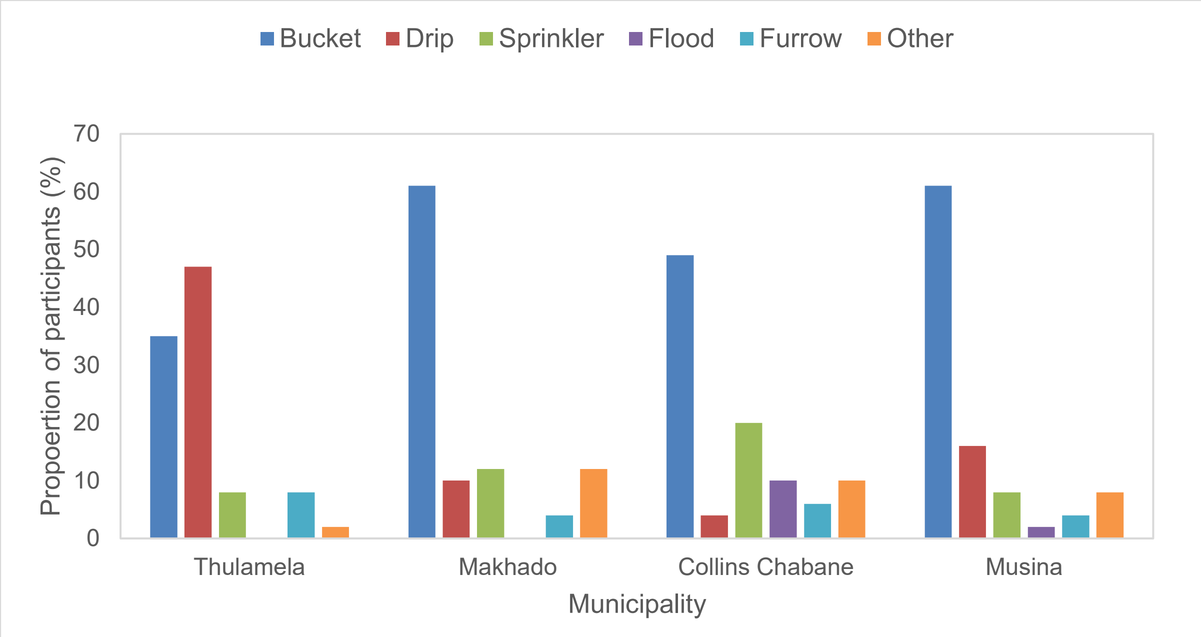

Figure 31. Irrigation systems used by the participants within each municipality

The respondents have gone to the extent of listing names of traditional leaf vegetables that they think can be planted in water-limited areas (Figure 32). Approximately 11% of respondents listed Jute mallow among the traditional leaf vegetables that require less water. This was followed by Amaranths (10%) and Cucurbits (8%), respectively.

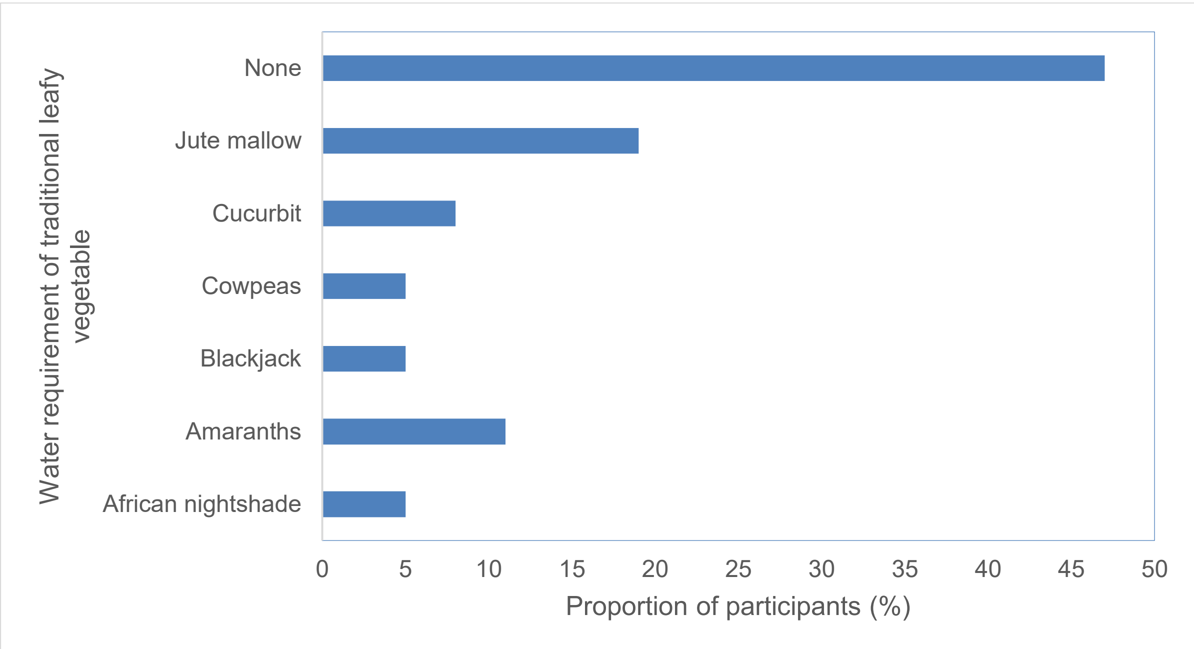

Figure 32: Traditional leafy vegetables that require less water

Apart from water, crops require nutrient elements to grow and produce. However, it was observed in this study that a large number of the participants (42%) who cultivated traditional leafy vegetables did not apply fertilisers (Table 10). About 33% of the respondent indicated that they used organic fertiliser to supply nutrients to their crops. Only 4% of the respondents applied chemical fertilisers.

Table 10. Forms of fertilisers of the respondents within each local municipality

Municipality	Distribution (%)			
	Forms of fertilizers used			
	Chemical	**Organic**	**Both**	**None**
Thulamela	8 (2%)	8 (2%)	45 (11%)	39 (10%)
Makhado	0 (0%)	37 (9%)	8 (2%)	55 (14%)
Collins Chabane	2 (1%)	20 (5%)	4 (1%)	74 (18%)
Musina	6 (2%)	35 (7%)	26 (7%)	33 (8%)
Chi-square	68.143			
Significance	<.0001			

Chi-square (X2) significant at the 5% probability level.

Traditional leafy vegetables are grown for their leaves, which are harvested at a specific time. The time to harvest leaves differs from one species to another. Table 11 shows the quantity of leaves that the participants harvested per season. Most of the participants (30%) harvested about 1 kg of leaves per season, whereas 29% indicated that they harvested more than 5 kg of leaves per season. However, most of the respondents in the Thulamela local municipality indicated that they harvested between 2 and 3 kg of leaves per season. Participants were asked what to do with leafy vegetables if they produced more than what they could consume (Figure 33). The majority of participants (54%) indicated that they share with their neighbours, while 33% indicated that they dry vegetable leaves so they can use them later.

Table 11. Quantity of traditional leafy vegetables (kg season^{-1}) harvested by the respondents within the Vhembe district

Municipality	The quantity of leaves harvested (Kg season^{-1})			
	1	**2-3**	**4-5**	**>5**
Thulamela	14 (4%)	15 (4%)	12 (3%)	59 (14%)
Makhado	29 (7%)	41(10%)	16 (4%)	14 (4%)
Collins Chabane	51(13%)	14 (4%)	16 (4%)	18 (4%)
Musina	26 7%)	25 (6%)	25 (6%)	24 (6%)
Chi-square	44.747			
Significance	<.0001			

Chi-square (X2) significant at the 5% probability level.

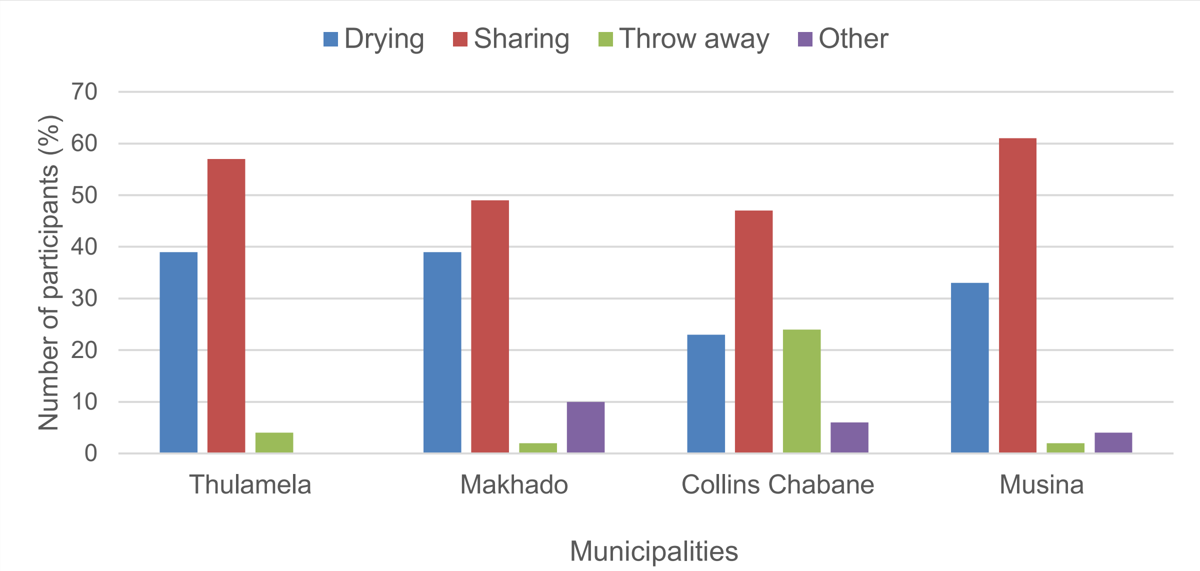

Figure 33. Responses regarding the extra traditional leafy vegetables produced by the participants

About 45% of participants indicated that raising awareness of the value of traditional leaf vegetables could help address some challenges (Figure 34). In addition, 29% of the participants believed that if the government provided them with water, they would be able to produce enormous quantities of these vegetables.

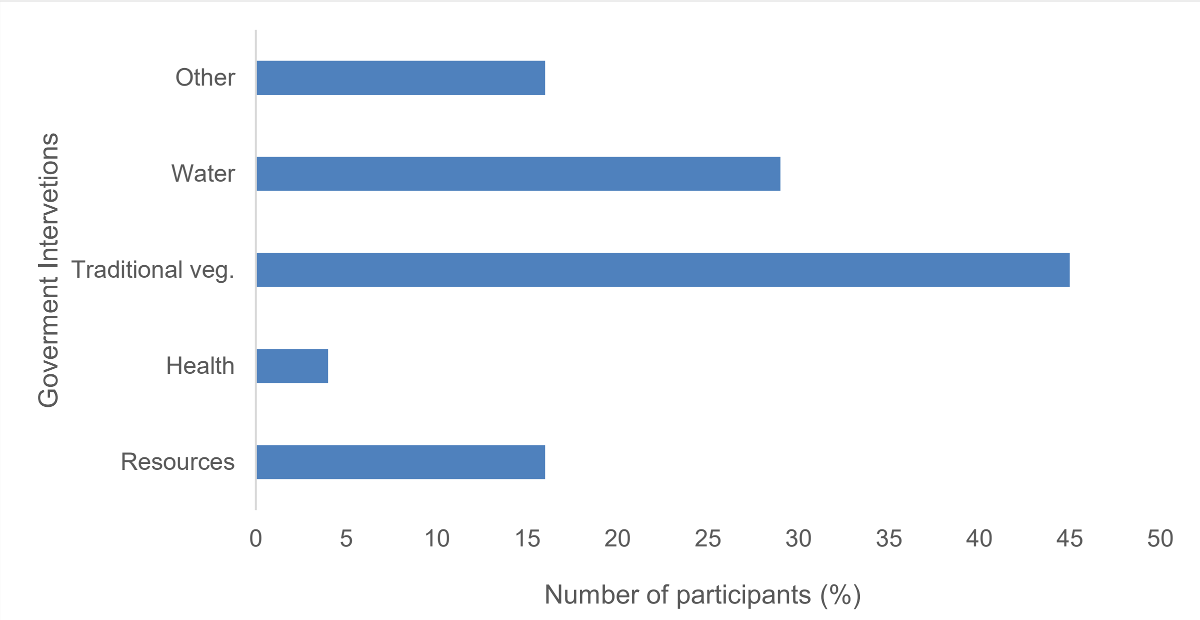

Figure 34. Government intervention to address challenges faced by producers of traditional leafy vegetables.

This study observed that the majority (60%) of participants planted traditional leafy vegetables during the summer months (Figure 35). However, about 15% of the respondents planted their vegetables during winter, given that we have summer and winter growing seasons.

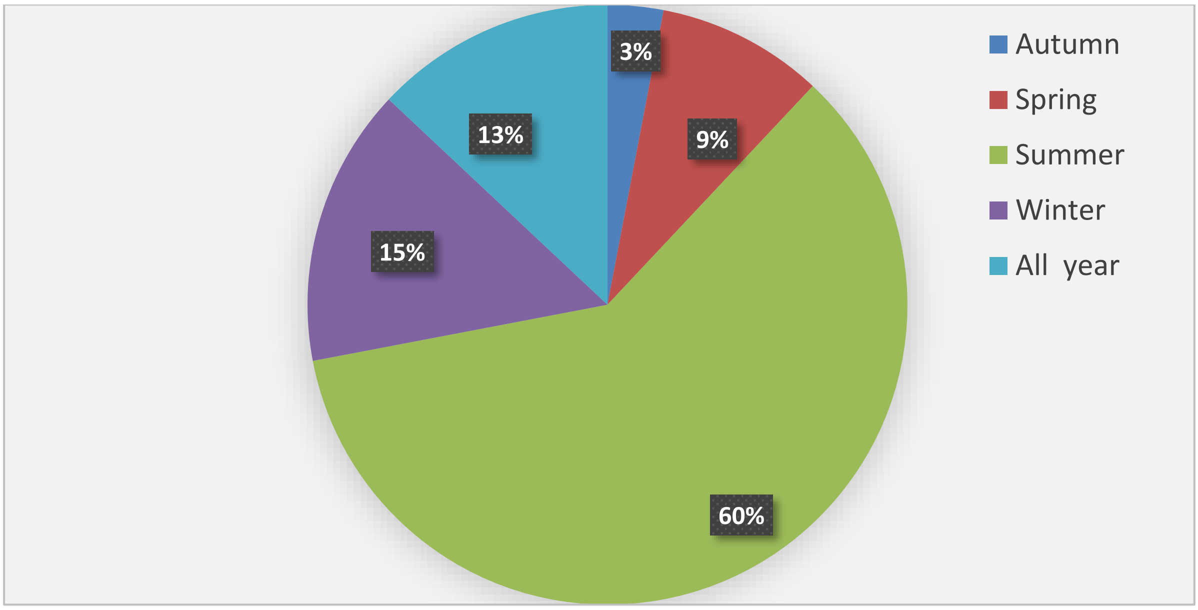

Figure 35. Seasons to plant traditional leafy vegetables.

3.3.5 The selling and marketing of traditional leafy vegetables in Vhembe district

Some participants sell traditional leafy vegetables for various reasons. A large proportion of participants (41%) indicated that they sell traditional leaf vegetables to generate income (Table 12a). Participants identified African nightshade (23%), Amaranths (14%), and Mustard (9%) as the traditional leafy vegetables that can generate more income in the Vhembe district (Table 12b). Table 12b showed the lists of the traditional leaf vegetables most favoured by the customers in the marketplaces. Jute mallow tops the list, followed by Mustard (13%), Amaranths (12%), Cucurbit (12%), Okra (10%) and African nightshade (10%). Some of the participants indicated that vegetable spoilage (10%), non-paying customers (9%), lack of market (8%), and transport costs (8%) were the most challenging factors when selling traditional leaf vegetables in the Vhembe district (Table 12 c). It was interesting to note that some respondents have contracts to supply traditional vegetables to retailers such as Boxer, Spar, Roots, Pick'n Pay, and Shoprite. This can serve as motivation for the others who want to produce traditional leafy vegetables for sale. About 15% of participants believe that customers can be attracted to buy traditional leafy vegetables simply by providing high-quality ones (Table 12 d). Only 5% of the participants think that providing the best customer service can make the seller a better competitor in the market. It was fascinating to observe that about 60% of participants agreed that cultivating traditional vegetables can alleviate poverty in the study area (Table 12e).

Table 12. Participants' perceptions about factors that affect the selling of traditional leafy vegetables

Variable	Frequency	Percent
A) Reasons for selling traditional leaf vegetables		
▪ Food security	5	3
▪ Passion	3	1
▪ High demand	10	5
▪ Generating income	80	41
▪ None	98	50
Total	196	100
B) Traditional leaf vegetables capable of generating income		
▪ African night shade	44	23
▪ Amaranthus	28	14
▪ Cowpea leaves	3	1
▪ Cucurbit	11	6
▪ Jute mallow	8	4
▪ Mustard	18	9
▪ Okra	8	4
▪ Other	2	1
▪ None	74	38
Total	196	100
C) Challenges of selling traditional leaf vegetables		
▪ Lack of supplier	12	6
▪ Lack of market	16	8
▪ Low selling price	5	2
▪ Non-paying customers	18	9
▪ Competition	5	3
▪ Spoilage	19	10
▪ Transport cost	15	8
▪ None	106	54
Total	196	100
D) Marketing strategies to attract more customers		
▪ Better customer service	10	5
▪ Market expansion	3	1
▪ Produce more traditional leaf vegetables	3	2
▪ Price reduction	5	3
▪ Sell high quality vegetables	39	15
▪ Out-of-season selling	4	2
▪ None	141	72
Total	196	100
E) Poverty alleviation through selling traditional vegetables		
▪ Yes	118	60
▪ No	78	40
Total	196	100

It was observed that the participants sell traditional leafy vegetables for various reasons. Figure 36 shows the various places where the participants sourced their traditional leafy vegetables for selling. About 44% of participants stated that they buy traditional leafy vegetables from producers, followed by those who grow their own vegetables for sale (28%). These have indicated that they produce traditional vegetables from their home gardens. Only 2% of the respondents collected traditional leafy vegetables from the wild. However, about 39% of the respondents in the Makhado local municipality obtained traditional leafy vegetables for selling from their own home gardens.

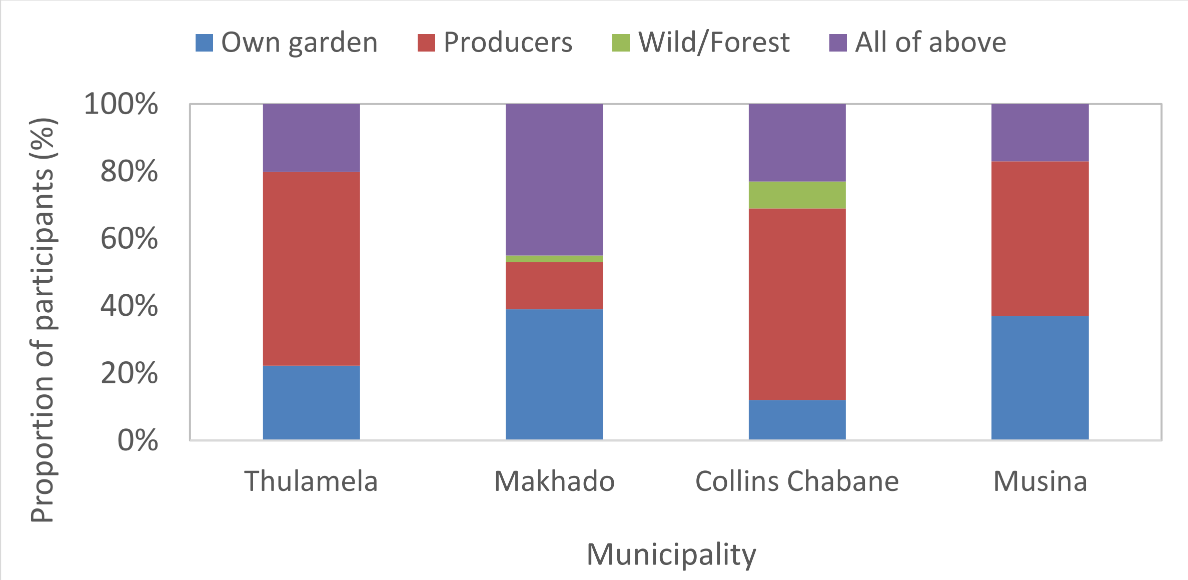

Figure 36. Sources of traditional leafy vegetables within the study area

A large number of participants stated that they sell their products in a formal market (35%) and on the roadside (34%), respectively (Table 13). Only 16% move from house to house, selling traditional leafy vegetables. Makhado local municipality had an enormous number (61%) of participants who sell their produce along the roadside. Unlike formal markets, roadside markets are temporary and operate only when traditional leafy vegetables are available. Figure 37 shows the distinct types of customers who purchase traditional leafy vegetables. The list includes local people, caterers, tourists and retail shops. However, local people (61%) dominated the list. About 8% of the respondents in Thulamela and Musina sell their traditional leafy vegetables to the retailers. About 49% of the participants sell a bunch of traditional leafy vegetables at between R1,00 and R5,00, while 31% range their prices between R6,00 and R12,00 (Table 14).

Table 13. Methods of traditional leafy vegetable selling within each local municipality

Municipality	**Distribution (%)**			
	Selling method			
	House to House	**Market place**	**Roadside**	**Other**
Thulamela	16 (4%)	49 (12%)	18 (5%)	16 (4%)
Makhado	20 (5%)	14 (4%)	61 (15%)	4 (1%)
Collins Chabane	4 (1%)	47 (12%)	39 (9%)	10 (3%)
Musina	24 (6%)	29 (7%)	18 (5%)	29 (7%)
Chi-square	47.776			
Significance	<.0001			

Chi-square (X2) significant at the 5% probability level.

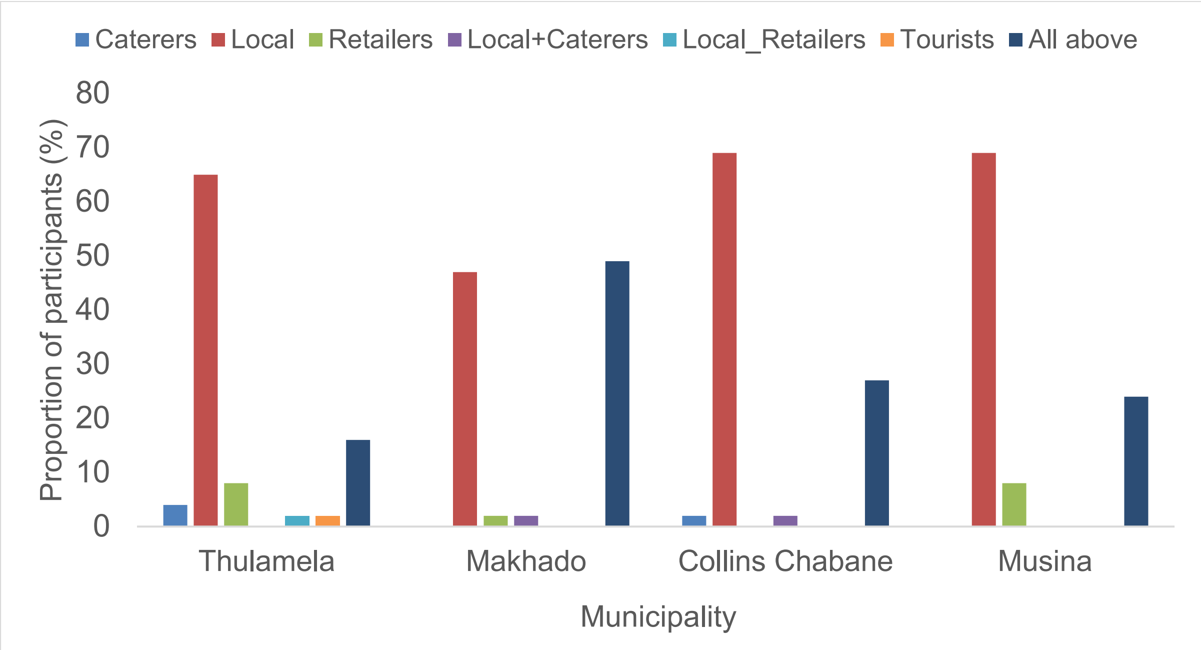

Figure 37. Type of customers for the respondents within each local municipality

Table 14. Selling prices of traditional leafy vegetables in the study area

Price	Frequency	Percentage
R 1,00 – R5,00	96	49
R 6,00 – R12,00	60	31
R 13,00 – R19,00	25	13
R 20,00 – R26,00	11	5
R 27,00 – R30,00	4	2

3.4. DISCUSSION

3.4.1. Characteristics of the participants

The findings of this study showed that most of the participants in the study area were men. This is not surprising, since a large number of respondents were from the rural areas of the Vhembe district. In rural areas where land is under the chief, men receive preferential treatment in land allocation, giving them an upper hand in farming compared to women. In South Africa, women residing in marginalised communities, particularly those in rural areas, face significant barriers when it comes to accessing economic resources. Their struggles are often compounded by systemic inequalities, limited infrastructure, and a lack of support services, which further entrench their economic subjugation. These challenges not only hinder their ability to achieve financial independence but also contribute to a cycle of poverty that impacts generations (Benjaminsen & Lund, 2018). It was interesting to note that both young and old people participated in the survey, suggesting effective knowledge dissemination from older, experienced people to the younger generation in the Vhembe district. Many of the participants were youths aged 16 to 35, which is very unusual, especially in the farming sector. This clearly indicates a shift in mentality among the youth, who previously saw agriculture as an activity for older people. Youth are now beginning to view farming as an opportunity to create jobs and earn income, given the high unemployment rate in the study area (August 2020; Giwu, 2023). Youth involvement in plant farming is vital for future food security, bringing innovation, tech adoption (precision farming, digital marketing), and addressing high youth unemployment by creating diverse agro-businesses, but requires overcoming barriers like negative perceptions (August 2020), lack of skills/finance/land access through targeted education, mentorship, and making agriculture a modern, profitable business, not just manual labor (Aabi et al., 2023; Giwu et al., 2024). Many participants have a basic level of education and consider farming as their only hope of generating income. The educational level of individuals significantly influences the knowledge, perception, and consumption of traditional vegetables. Generally, higher levels of education correlate with increased consumption of traditional leafy vegetables, often due to greater awareness of their nutritional benefits, though some studies note a decline driven by changing perceptions among youth. Salary was mentioned by many participants as the major source of income in the study area, followed by farming. This is not surprising, since most respondents are still active and likely working in various organisations where they earn wages or salaries. The majority of participants own land of less than 1 hectare. Lack of sufficient land was considered by some participants a major factor limiting the production of traditional leaf vegetables. Although a large number of the participants alluded that they only use traditional leafy vegetables, there was a considerable number (30%) of the participants who consume, produce, and sell traditional leafy vegetables.

3.4.2. Identification of different traditional leafy vegetables and their roles in society

South Africa is rich in traditional leafy vegetables, which are either harvested from forests or grown in home gardens (van Rensburg et al., 2007; Thovhogi et al., 2021). Although there is growing interest in the consumption of traditional leafy vegetables in the Vhembe district (Nesamvuni et al., 2001), people differ when it comes to the type of traditional leafy vegetable that they prefer to consume. Many factors influence people's preference for one indigenous vegetable over another. These factors include location, availability, taste, appearance, culture, social class, age and level of education, amongst others. The findings of this survey showed that there were about 16 different types of traditional leafy vegetables which were identified by the participants as the most popular in Vhembe district. These vegetables included Jute mallow, Amaranthus, okra, African nightshade, spider plant, cucurbit, spindle nettle, bitter gout, and cowpeas. However, Jute mallow, Amaranthus, African night shade and okra were on top of the list. This does not come as a surprise, as these traditional leaf vegetables dominate markets in the Vhembe district. Mokganya et al. (2019) listed about 46 indigenous vegetables consumed in Vhembe district, whereas Maanda and Bhat (2010) listed 43 indigenous vegetables in the same place. Numerous uses of these vegetables in traditional medicine have been documented. Mokganya & Tshisikhawe (2019) documented 13 wild vegetables with ethnomedicinal properties in Vhembe District Municipality. Although there is no agreement on the number of traditional leafy vegetables consumed in Vhembe district, the literature review noted that most researchers included many indigenous vegetables on their lists.

3.4.3. Consumption, of leafy vegetables in Vhembe district

The use of traditional leafy vegetables is known to stabilise food security and alleviate poverty by providing a variety of income-generating opportunities for farmers, ensuring income security (Adjatin et al., 2019; Ayodeji et al., 2021). The cultivation and utilisation of traditional leafy vegetables are expanding in South Africa, prompting interest among South African researchers (Van Rensburg et al., 2007). Participants mentioned several reasons for consuming traditional leafy vegetables. It was found that the majority of respondents consume traditional leafy vegetables for their medicinal and nutritional value. The participants indicated that traditional leafy vegetables have nutrients, minerals, protein, fibre, carbohydrates, vitamins and antioxidants. This finding concurs with the results of Mungofa et al. (2022), who reported that a large number of people consume traditional leaf vegetables either to cure some ailments or supplement minerals and vitamins into their bodies. Abukutsa-Onyango et al. (2003) and Maseko et al. (2018) expressed a similar sentiment. These authors have listed some of the crucial compounds that are necessary for good health. These compounds include vitamins, minerals, antioxidants, and even anti-cancer factors. This would be especially helpful in impoverished rural communities where residents cannot afford to buy vegetables. Mungofa et al. (2022) and Sivakumar et al. (2018) also listed important compounds found in traditional leafy vegetables that provide health benefits to consumers. These dietary phytochemicals include phenolic compounds, flavonoids, dietary fibre, carotene, glucosinolates and vitamins. The cultivation and utilisation of traditional leafy vegetables have been viewed by many as another way to achieve the Sustainable Development Goals (SDGs) 1, 2, and 3 of the United Nations General Assembly in 2015. These SDGs focus on improved nutrition, the end of hunger, food security, and sustainable agriculture. Cultivation and utilisation of traditional leafy vegetables are integral components of a quality diet (Kennedy et al., 2007; Modi, 2015). Several of these indigenous leafy vegetables have been reported to have significant nutritional potential for rural people's diets.

3.4.4 Cultivation of traditional leafy vegetables in Vhembe district

The majority of people in the Vhembe district produce traditional leafy vegetables to generate income. This clearly indicates that people are now aware of the potential of traditional leafy vegetables to alleviate poverty and create employment opportunities. Just like any other crop, traditional leafy vegetables require water to survive and produce. However, the fact that most of the three respondents indicated they do not irrigate their crops suggests a problem of water scarcity in the Vhembe district. As an adaptation strategy, respondents indicated that they plant traditional leafy vegetables that require less water. Most of them use water from the river and or municipal water to irrigate their vegetables. However, the issue of water requirements by traditional leafy vegetables needs further investigation. In case the participants produce more vegetables, they stipulated that they preserve excess traditional leafy vegetables in other forms so they can store them for longer and use them during the drought period/season when nothing is growing in the fields. Some participants have shown that they preserve traditional leafy vegetables to prevent spoilage. Traditional leafy vegetables are cooked and dried using sun (Sun drying methos) whereas other respondents have indicated that they half cooked the traditional leafy vegetables and store them in the deep freezer (Freezing method) for future use. Drying fresh vegetables and fruits reduces bulkiness and weight and so eases storage and transportation and avoids wastage (Ayua et al., 2017; Muchoki et al., 2025). However, further research is needed to examine the effects of preservation methods on the quality of traditional leafy vegetables in the Vhembe district.

3.4.5 The selling and marketing of traditional leafy vegetables in Vhembe district

As expected, most of the participants sell traditional leafy vegetables to generate income. Selling indigenous vegetables can assist smallholder farmers to earn extra income and thereby improve their standard of living. Commercialisation of indigenous vegetables can also create job opportunities and reduce the unemployment rate (Muhanji et al., 2011). Traditional leaf vegetables grow in the wild with little or no care at all and therefore can withstand harsh conditions (Faber et al., 2010; van Jaarsveld et al., 2014). This can be an advantage for rural farmers who lack agricultural inputs such as fertilisers, herbicides, pesticides, fungicides, and other resources used to enhance vegetable growth. This is interesting, as several authors repeatedly mentioned that the cultivation and sale of traditional leafy vegetables can improve the livelihoods of rural people. The commercialisation of traditional leafy vegetables has been reported to generate income and alleviate poverty, especially in rural and peri-urban areas (Muhanji et al., 2011; Mwema & Crewett, 2019). Pitso and Lebese (2014) have indicated that if traditional leafy vegetables are commercialised, this can enhance their production by smallholder farmers, thereby improving demand and contributing to income generation within rural communities. A similar sentiment was shared by Opondo and Owuor (2018), Nyaruwata et al. (2018), and Mwema & Crewett (2019.

The respondents have agreed that there is a market opportunity for traditional leafy vegetables in the study area, but the biggest challenge is that they cannot produce enough to meet market demand. The participants indicated that they require assistance from the government with agricultural resources such as land, finance, training, and water so that they can produce reasonable amounts of traditional leaf vegetables. The respondents used different platforms to sell their traditional leaf vegetables, with the majority selling their products in the formal market. Others have indicated that they sell traditional leafy vegetables along the roadside, while others move from house to house. Most roadside markets are temporary and only operate during the peak season, when there are plenty of traditional leafy vegetables to sell. The most potential buyers of traditional leafy vegetables are the local people, especially those who own catering companies. It was fascinating to observe that a few participants had secured contracts with some of the biggest retail shops, such as Spar, Pick n' Pay, Boxer, Roots, and ShopRite. This can serve as motivation, especially for those who want to produce enormous quantities of traditional leaf vegetables.

3.5. CONCLUSIONS

The survey concluded that people across the Vhembe district consume, produce, and sell traditional leafy vegetables collected from various places for distinct reasons. People showed to have a vast amount of native knowledge regarding the cultivation and utilisation of traditional leafy vegetables. However, this knowledge is not well-documented and supported by scientific studies. Based on this survey's findings, encouraging the cultivation and consumption of traditional leafy vegetables can help address challenges such as food insecurity, hunger, and poverty. Several studies have reiterated the importance of consuming vegetables for human health. Currently, most traditional leafy vegetables are sold in local markets and by hawkers, with little sold in big retailers such as Spar, Pick n' Pay, Boxer, Roots and ShopRite.

If properly executed, the production and sale of traditional leaf vegetables can generate additional income for smallholder farmers, create jobs, and reduce the unemployment rate. However, the fact that traditional leafy vegetables have received little scientific and academic attention as compared to exotic vegetables has led to them being considered as "food for the poor", especially by young people. Several authors have shown that greater research effort would increase the cultivation and utilisation of traditional leafy vegetables in the study area. In light of the above, it is recommended that agricultural policies include strategies that would encourage the cultivation and consumption of traditional leafy vegetables. The government must provide the necessary support, as reflected in this study's participants. The health and nutritional values of traditional leafy vegetables in the Vhembe district require further thorough investigation.

CHAPTER 4: EFFECT OF MACADAMIA HUSK COMPOST ON GROWTH, YIELD, AND NUTRITIONAL QUALITY OF JUTE MALLOW (*CORCHORUS OLITORIUS*) GROWN UNDER DIFFERENT WATER REGIMES

4.1 INTRODUCTION

Traditional leafy vegetables (TLVs) provide dietary diversity, micronutrients, and bio-active compounds to poor rural households in most African countries (Smith & Eyzaguirre, 2007; Maseko et al., 2017; Nyathi et al., 2018). In South Africa, TLVs are obtained mainly from the wild or cultivated land and are predominantly available during the summer season (Jansen van Rensburg et al., 2007; Voster et al., 2007). Moreover, there are diverse TLVs in South Africa that can grow in marginal production areas (Maseko et al., 2019). Although jute mallow (*Corchorus olitorius*) is amongst commonly consumed ILVs in the province of Limpopo and most common in South Africa, majority of the population does not cultivate the crop as it can grow in the wild (Jansen van Rensburg et al., 2014; Tabit et al., 2018; Maseko et al., 2020). Furthermore, consumption of ILVs in Limpopo province is affected by socioeconomic position, gender, family size, and age (Zulu et al., 2022). Jute mallow has the potential to provide food diversity and ensure food security; however, it remains underutilised. Moreover, water stress and poor soil fertility are constraints on jute mallow productivity. However, there is limited information on agronomic practices such as the application of organic fertiliser and water inputs to promote the production of jute mallow.

The use of inorganic fertilisers in crop production is common due to their perceived benefits in crop yield; however, there is a growing concern about their negative impact on the environment and human health (Jote, 2023). Organic manure (OM) such as composted farmyard manure, poultry and kraal manure increased growth and yield of TLVs such as *Cleome gynandra* and *Amaranthus cruentus* (Ng'etich et al., 2012; Seeiso & Materechera, 2013). However, there is limited documented information on growth, yield and nutrient uptake of jute mallow in response to OM such as MHC under varying water regimes. it is important to evaluate the impact of different water regimes and MHC on the growth and yield of these traditional leafy vegetables to optimise irrigation strategies for sustainable and efficient production. This study will provide information on optimising organic fertilisers and water for the sustainable production of jute mallow. Also, the study aims to provide information that can improve the productivity of jute mallow and, consequently, address food insecurity in communities that are reliant on these vegetables.

4.1.1. Aim and objectives of the study

4.1.1.1. Aim

To investigate the effect of macadamia husk compost on the growth, yield, and nutritional content of jute mallow grown under different water regimes.

4.1.1.2. Specific objectives

i) To evaluate the effect of macadamia husk compost on soil nutrient availability.
ii) To evaluate the effect of macadamia husk compost on growth and leaf yield of jute mallow grown under different water regimes.
iii) To evaluate the effect of macadamia husk compost and different water regimes on the nutritional and phytochemical content of jute mallow.

4.1.2. Hypotheses

i. Macadamia husk compost will affect the soil nutrient availability.
ii. Macadamia husk compost will affect growth, yield, and nutrient uptake by jute mallow grown under different water regimes.
iii. Macadamia husk compost and different water regimes will affect the nutritional and phytochemical content of jute mallow.

4.2. MATERIALS AND METHODS

4.2.1. Location and characteristics of the experimental site

The experiment was carried out in 2023/2024 and 2024/2025 summer seasons at the Agricultural Research Council (ARC) farm in Levubu (23° 05′ 33" S and 30° 17' 15" E), Limpopo Province, South Africa (Figure 38). Levubu is in a subtropical climate zone with an average annual rainfall of 900 mm, with the highest rainfall reported from December to February. The temperatures in Levubu ranged from about 24℃ to 40℃ in summer and between 20℃ and 26℃ in winter (Schulze & Maharaj, 2003). Soil in the Levubu area are predominantly alluvial and/or sandy-clay-loam (FAO, 2009).

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Figure 38. ARC-TSC Levubu Research Farm, the red rectangle outlines the experimental site (adapted from Google map)

4.2.2 Preparation of compost

The Agricultural Research Council -Tropical and Subtropical Crops (ARC-ITSC) in Levubu produces about 50 tons of macadamia nuts annually (Maselesele et al., 2020). After dehusking of macadamia nuts, the husks were dumped at a designated composting site. The husks were piled into a heap and left to decompose until they reached maturity. During the composting process, a tractor was used to toss and turn the husks to improve and hasten the decomposition process (Dalzell et al., 1987). The maturity of compost was assessed using the compost maturity baseline, which uses colour and distinctive smell to determine the maturity (Bittenbender et al.,1998). The compost used in this study was left to mature for 18 months, during which it darkened to a dark black and developed a distinct smell. A composite sample of 2 Kg was collected from different angles of mature compost. The MHC was analysed for chemical properties such as pH, N, available P, K, Ca, Mg, Fe, B, Zn, Cu, Mn, organic C, and C:N ratio.

4.2.3 Preparation of seedlings

Seedlings were prepared in seedbeds. The soil in the seedbeds was ploughed and tilled to loosen the soil before planting. Jute mallow seeds were submerged in room temperature water for 72 hours before planting in a container. The water was drained from the container, leaving only the seeds to remain in the container. Thereafter, the seeds were planted in rows on the seedbeds at 20 cm depth. The seedbeds were irrigated using sprinklers.

4.2.4 Experimental design and layout

The experiment was a complete randomised design, with a factorial combination of four fertiliser treatments (0 t ha^{-1} MHC), 30 t ha^{-1} MHC, 60 t ha^{-1} MHC, and NPK (100:60:60 kg/ha); and three irrigation treatments at 30%, 60%, and 100% field capacity replicated three times. Macadamia husk compost rates were incorporated into the soil in polythene bags and incubated for a week. Moreover, NPK fertiliser was applied a week after planting. Jute mallow was used as a test crop.

4.2.5 Soil sampling and analysis

A composite soil sample was collected from a selected field for analysis before planting. The soil was collected at a depth of 0-15 cm using an auger. After harvesting the plants from the polythene bags, soil samples were collected at 0-15 cm depth from each treatment using an auger. The collected samples were analysed for soil chemical properties to determine the effect of macadamia husk compost and NPK fertiliser. Soil samples were analysed for soil water holding capacity and for chemical properties, which included soil pH, electrical conductivity (EC), magnesium (Mg), calcium (Ca), zinc (Zn), potassium (K), total nitrogen (N), phosphorus (P), organic carbon, and organic matter. Soil pH was measured in a soil:water supernatant at a 1:5 ratio using a pH meter (Thomas, 1996; Okalebo et al., 2002). Soil electrical conductivity was measured using a conductivity meter (Rhoades et al., 1989). Soil organic carbon and soil organic matter were analysed to provide complementary information on soil health and fertility. Soil organic carbon was determined using the Walkley and Black method (Walkley & Black, 1934). Potassium, calcium, and magnesium were determined using an Atomic

Absorption spectrophotometer (AAS) (Bray & Kurtz, 1945). The soil phosphorus concentration was assessed using the Bray-1 method. Total soil nitrogen was determined using the micro-Kjeldahl digestion, distillation, and titration method (Bremmer, 1996). Total nitrogen concentration was calculated based on the volume of acid consumed during titration. Water holding capacity was determined using the filter paper method according to Smith and Mullins, (1996).

4.2.6 Plant growth parameters

Data collection for growth parameters (plant height (cm), stem diameter (mm), number of branches per plant, chlorophyll content index from five plants per treatment commenced 5 weeks after planting and continued at biweekly intervals until 11 weeks after planting. Plant height was measured using a measuring tape from the ground level to the tip or apex of the main stem or branch in cm. Stem diameter was measured using a vernier calliper in mm. The number of branches per plant for each treatment was counted. Chlorophyll content index was measured from the adaxial surface of the leaf using a chlorophyll content meter (Opti-Sciences CCM-200 plus). Leaves and roots were harvested in 11 weeks from 5 plants per treatment per replicate and weighed immediately to determine fresh weight. Leaf samples were air-dried at room temperature for 72 hours and weighed to determine leaf dry weight. Roots were harvested, oven-dried at 70 ºC for 48 hours and weighed to determine root dry weight. Root:shoot ratio was calculated using a method described by Bonifas et al., 2005. Jute mallow roots biomass was determined after harvest at 77 DAT. The roots were weighed to determine fresh weight. Furthermore, the roots were oven dried at 70 ºC for 24 hours and weighed to determine the dry weight.

4.2.7 Determination of nutritional and phytochemical content of jute mallow

4.2.7.1 Ash content

About 2 g of jute mallow leaf samples were weighed into crucibles. The crucibles were placed in a muffle furnace for 24 hours at 550 ºC. The samples were then left to cool for 2 hours in the muffle furnace. After 2 hours, the samples were removed from the muffle furnace using long-handled metal tongs and placed in a tray. The tray with the samples was then placed in the dessicator for 30 minutes, after which the samples reached room temperature. The ash was weighed to determine the ash content of the samples.

4.2.7.2 Antioxidant activity, total phenolic content, and total flavonoids sample extraction

About 2g of the milled leaf samples were weighed, and 20 ml of 80% methanol was added to the sample. The mixtures were sonicated for 15 minutes in an ultrasonic water bath. The mixtures were centrifuged at 3000 rpm for 10 minutes to separate supernatants. The liquid portion of the mixtures was separated from the solid residue and Whatman filter paper was used to filter the supernatants. The supernatants were used to analyse antioxidant activity, total phenol content, and total flavonoid content.

Antioxidant activity

1,1-Diphenyl-2-picrylhydrazyl (DPPH) assay
Antioxidant activity was measured using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging activity (Souza et al., 2012; Sarker & Oba, 2018).
Ferric reducing antioxidant power (FRAP) assay
Antioxidant activity was determined using the Ferric reducing antioxidant power (FRAP) assay according to Benzie and Strain (1996) with minor modifications.

Total flavonoid content (TFC)

The total flavonoid content of jute mallow extracts was estimated using the aluminium chloride colourimetric method described by Obeng et al. (2020).

Total phenolic content (TPC)

Total phenolic contentof jute mallow extracts was determined using the Folin-Ciocalteu's colourimetric method according to Singleton & Rossi (1965).

4.2.8. Data analysis

Data was subjected to a 2-way ANOVA using GenStat software version 17 and means were separated using Fisher's least significance difference test at $p \leq 0.05$.

4.3. RESULTS

4.3.1. Growth and yield of jute mallow in response to macadamia husk compost and water regimes

The effect of MHC and water regimes on jute mallow's growth parameters (number of branches, plant height, stem diameter) and chlorophyll content for two growing seasons (2023/2024 and 2024/2025) is presented in Table 15. Fertiliser treatments had significant effects on the chlorophyll content and number of branches at $P<0.01$ and $P<0.001$, respectively at 49 days after planting in the 2023/2024 season. Relative to the control, NPK increased the number of branches per plant by 39% (5.67 vs 3.44), whereas MHC rates showed no significant difference during the 2023/2024 seasons (Table 15). In additionally, no significant effect of fertilizers was recorded on plant height and stem diameter in 2023/2024 at the vegetative stages (49 days after planting).

There was a significant effect of irrigation treatments on the number of branches, plant height, stem diameter, and chlorophyll content at 49 days after planting in 2023/2024. Relative to the control, deficit irrigation at 30% FC decreased the number of branches by 39% (4.97 vs 3.05), while 60% FC had no significant difference to the control at 100% FC. In addition, plant height and stem diameter decreased at 30% FC by 17% (58.05 vs 48.40 cm), and 13% (5.2 vs 4.5 mm), respectively. In contrast, chlorophyll content increased with deficit irrigation by 13% (14.69 vs 12.74) during the vegetative stage. irrigation at 100% FC showed significant difference amongst the irrigation treatments on stem diameter (Table 15).

In the 2024/2025 planting season, fertilizer treatments significantly affect number of branches per plant, plant height, stem diameter, and chlorophyll content at $P<0.01$, $P<0.001$, $P<0.001$, and $P<0.01$, respectively (Table 15). The application of fertilizer treatments had significant influence on plant height and stem diameter. Application of MHC at 30 t ha^{-1} had increased both parameters by 24% (97.41 vs 74.49 cm) and 24% (7.52 vs 5.72 mm) respectively. Furthermore, 60 t ha^{-1} MHC increased plant height and stem diameter by 23% (97.25 vs 74.49 cm) and 19% (7.10 vs 5.72 mm). The application of NPK increased chlorophyll content by 6% (14.65 vs 13.75), whereas 60 t ha^{-1} MHC decreased chlorophyll content by 11% (12.23 vs 13.75). Relative to the control, 30 t ha^{-1} of MHC increased the number of branches by 40% (8.11 vs 4.87) whereas applying 60 t ha^{-1} of MHC increased the number of branches by 26% (6.58 vs to 4.87). Irrigation treatments had a significant effect on the number of branches, plant height, stem diameter, and chlorophyll content at 49 DAT in 2023/2024 but not in the 2024/2025 growing season.

Table 15: Effects of macadamia husk compost and water regimes on growth parameters and chlorophyll content of jute mallow at 49 days after planting.

Treatments	Number of Branches	Plant Height (cm)	Stem Diameter (mm)	Chlorophyll Content
Fertilizer				
Control	3.44b	52.5	4.67	12.24 b
NPK	5.67a	55.2	5.02	15.25 a
30 t ha^{-1} MHC	3.82b	55.4	4.88	12.65 b
60 t ha^{-1} MHC	3.78b	51.6	4.79	12.73 b
L. S. D	*1.23*	*6.39*	*0.41*	*1.15*
Irrigation				
30% FC	3.05b	48.40b	4.5b	14.69a
60% FC	4.52a	54.59a	4.82b	12.22b
100% FC	4.97a	58.05a	5.2a	12.74b
L.S. D	*1.06*	*5.54*	*1.06*	*1.00*
F- Statistics				
Fertilizer	9.12**	32.38^{ns}	0.20^{ns}	16.95***
Irrigation	12.05***	287.26**	1.49***	20.27***
Fertilizer*Irrigation	3.14^{ns}	56.90^{ns}	0.28^{ns}	1.59^{ns}
CV (%)	30.1	8.7	30.1	8.9
Fertilizer				
Control	4.87 b	74.49 b	5.72 b	13.75 ab
NPK	6.16 b	71.49 b	5.64 b	14.65 a
30 t ha^{-1} MHC	8.11 a	97.41 a	7.52 a	12.74 bc
60 t ha^{-1} MHC	6.58 ab	97.25 a	7.10 a	12.23 c
L.S.D	*1.92*	*8.45*	*0.97*	*1.46*
Irrigation				
30% FC	5.55	83.8	6.26	12.94
60% FC	6.97	85.0	6.50	13.59
100% FC	6.77	86.7	6.73	13.50
L.S.D	*2.14*	*13.24*	*0.98*	*1.49*
F- Statistics				
Fertilizer	16.10**	1791.1***	8.25***	10.40**
Irrigation	7.05^{ns}	24.9^{ns}	0.66^{ns}	1.50^{ns}
Fertilizer* Irrigation	5.35^{ns}	90.2^{ns}	0.57^{ns}	2.49^{ns}
CV (%)	38.5	18	17.5	12.9

***; **; * = significant at the 0.1%, 1% and 5% probability level respectively. Means with the same letters are not significantly different.

Fertilizer treatments had no significant effect on plant height, number of branches per plant, stem diameter, and chlorophyll content during the 2023/2024 growing season at the reproductive stage of the plants (Table 16). However, the irrigation treatments affected stem diameter during the first season (2023/2024) at $p<0.01$. Irrigation at 30% FC showed a decrease in stem diameter by 10% (5.43 vs 4.91 mm) at 77 days after planting when compared to the control. Additionally, no significant variation was observed at 60% FC when compared to 30% FC and 100% FC (control).

Fertilizer treatments significantly affected plant height ($p<0.001$), and the number of branches ($p<0.01$) at 77 days after planting during the 2024/2025 season (Table 16). The application of 30 t ha^{-1} MHC significantly increased the number of branches and plant height by 49% (41.9 vs 21.3) and 26% (111.9 vs 83.3 cm), respectively. Fertilizer treatments had no significant effect on chlorophyll content and stem diameter during the reproductive stages of the plants. Moreover, irrigation showed no significant effect on the number of branches, plant height, stem diameter, and chlorophyll content at 77 days after planting during the 2024/2025. Furthermore, at 77 days after planting the interaction between fertilizer and irrigation had no significant effect on stem diameter, number of branches, plant height, and chlorophyll content in both seasons.

Fertilizer treatments showed significant effect on number of branches and chlorophyll content of jute mallow plants at a vegetative phase (49 days after planting) in both growing seasons (Table 16). However, NPK showed a significant increase in number of branches in 2023/2024, while in 2024/2025, applying MHC at the rate of 30 t ha^{-1} significantly increased number of branches at 49 days after planting. Moreover, control irrigation at 100% FC had high stem fresh weight whereas, deficit irrigation decreased the stem fresh weight. Additionally, 30% FC increased leaf chlorophyll content 2023/2024.

Table 16: Effects of macadamia husk compost and water regimes on growth parameters and chlorophyll content of jute mallow at 77 days after planting (2024/2025)

Treatments	Number of branches	Plant Height (cm)	stem Diameter (mm)	Chlorophyll Content
		2023/2024		
Fertilizer				
Control	66.9	12.96	5.19	14.34
NPK	67.5	15.04	5.44	12.74
30 t ha^{-1} MHC	68.7	15.02	5.08	11.94
60 t ha^{-1} MHC	64.2	13.22	4.96	12.82
L.S.D	*8.93*	*3.09*	*0.40*	*2.60*
Irrigation				
30% FC	62.8	13.23	4.91b	13.56
60% FC	66.0	14.18	5.16ab	12.64
100% FC	71.7	14.77	5.43a	12.68
L.s.d	*7.74*	*2.68*	*0.34*	*2.25*
F- Statistics				
Fertilizer	32.12^{ns}	11.41^{ns}	0.37^{ns}	9.07^{ns}
Irrigation	239.72^{ns}	7.24^{ns}	0.80**	3.27^{ns}
Fertiliser*Irrigation	40.02^{ns}	4.68^{ns}	0.30^{ns}	1.44^{ns}
CV (%)	13.7	22.5	1.8	20.5
		2024/2025		
Fertilizer				
Control	21.3 b	83.3 b	6.32	14.87
NPK	20.9 b	82.2 b	6.12	17.21
30 t ha^{-1} MHC	41.9 a	111.9 a	7.88	16.65
60 t ha^{-1} MHC	37.9 a	111.5 a	7.76	17.72
Lsd	*13.32*	*13.30*	*1.41*	*2.01*
Irrigation				
30% FC	29.4	95.9	6.76	15.62
60% FC	29.1	94.4	7.22	16.67
100% FC	33.0	101.3	7.09	17.55
L.s.d	*7.28*	*14.35*	*1.06*	*2.00*
F- Statistics				
Fertilizer	1087.66**	25175***	7.76^{ns}	13.84^{ns}
Irrigation	58.89^{ns}	157.5^{ns}	0.67^{ns}	11.23^{ns}
Fertilizer*Irrigation	124.33^{ns}	123.5^{ns}	0.54^{ns}	10.80^{ns}
CV (%)	27.6	17.1	17.4	13.9

***; **; * = significant at the 0.1%, 1% and 5% probability level respectively. Means with the same letters are not significantly different.

Macadamia husk compost at 30 and 60 t ha^{-1} had significantly increased fresh yield by 48% (45.05 vs 23.62 g) and 48% (45.68 vs 23.62 g) (Figure 39). Similarly, applying MHC at the rate of 30 and 60 t ha^{-1} had increased dry biomass by 44% (11.329 vs 6.371 g) and 48% (12.251 vs 6.371g). Therefore, the use of macadamia husk compost can be recommended to farmers to achieve optimal yield in the production of jute mallow. Irrigation at 60% FC was not significantly different to the control at 100% FC for both fresh and dry weight of jute mallow. However, deficit irrigation at 30% FC decreased jute mallow fresh and dry weight by 37% (42.66 vs 26.67 g), and 31% (10.874 vs 7.498g), relative to the control. Therefore, the use of moderate irrigation in jute mallow production can be recommended for optimal yield.

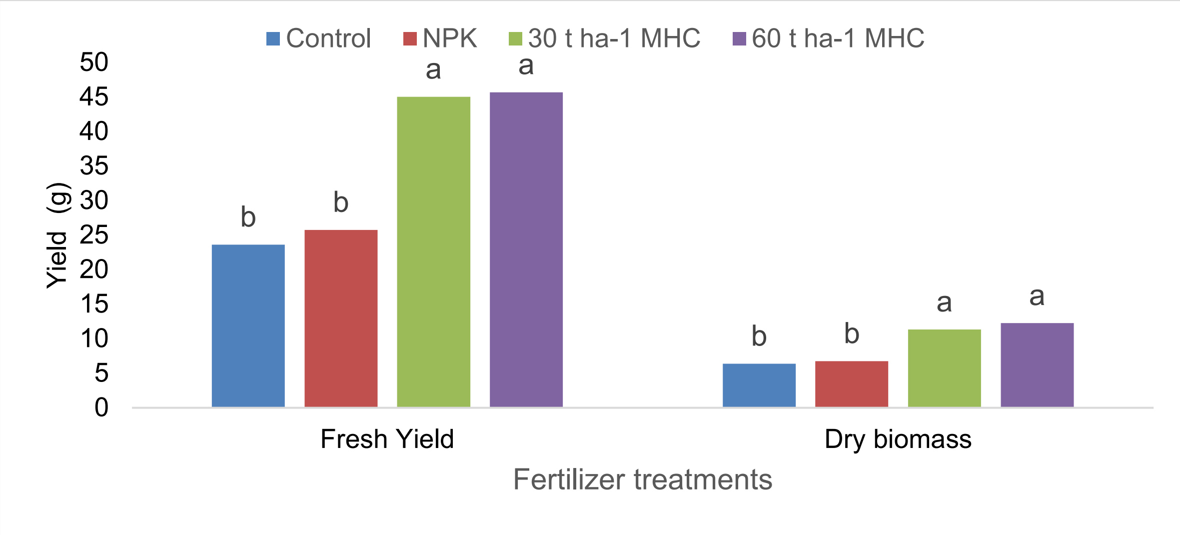

Figure 39. Response of Jute mallow's fresh and dry biomass to fertilizer treatments in 2024/2025

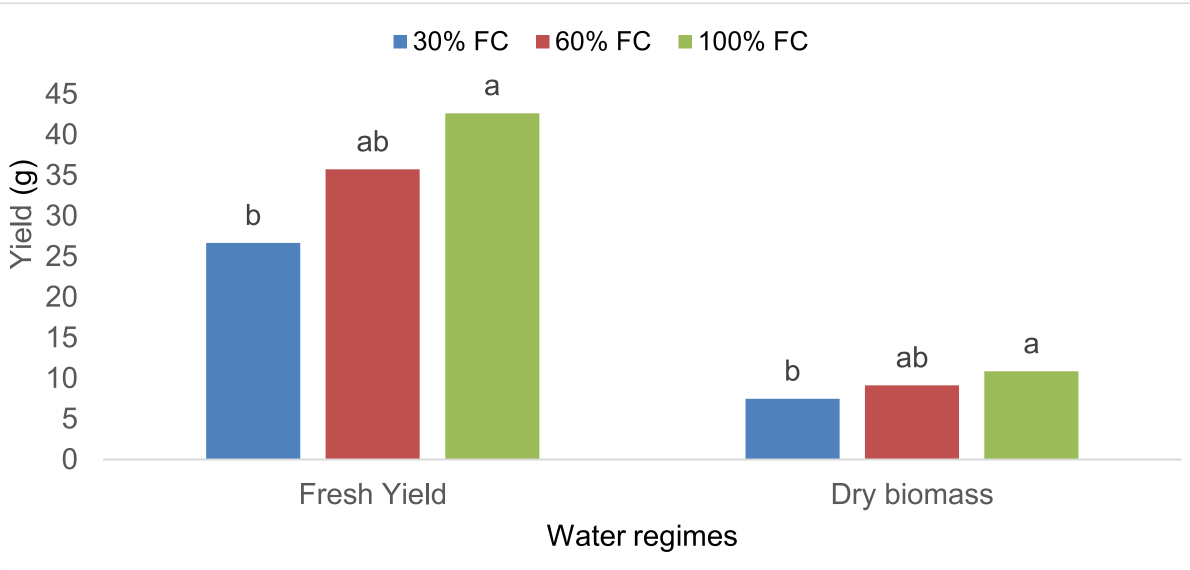

Figure 40. Response of jute mallow's fresh and dry weight to water regimes in 2024/2025

4.3.2 Response of leaf nutrient concentration to macadamia husk compost and water regimes

The water regimes and fertilizer treatments showed significant ($P<0.05$) effects on nutrient concentration such as manganese (Figure 41), potassium (Figure 42) and zinc (Figure 43). Fertilizer treatments and water regimes showed statistically significant effect on manganese concentration in jute mallow leaves. In addition, 30 t ha^{-1} of MHC at 60% FC showed an increase in Mn concentration, with

60 t ha^{-1} of MHC at 100% FC showing lowest concentration. The fertilizer and water treatments had significant ($p<0.05$) effects on potassium concentration in the jute mallow leaves, with 30 t ha^{-1} of MHC at 60% FC showing highest levels. Moreover, 60 t ha^{-1} of MHC at 100% showed significant levels of potassium concentration.

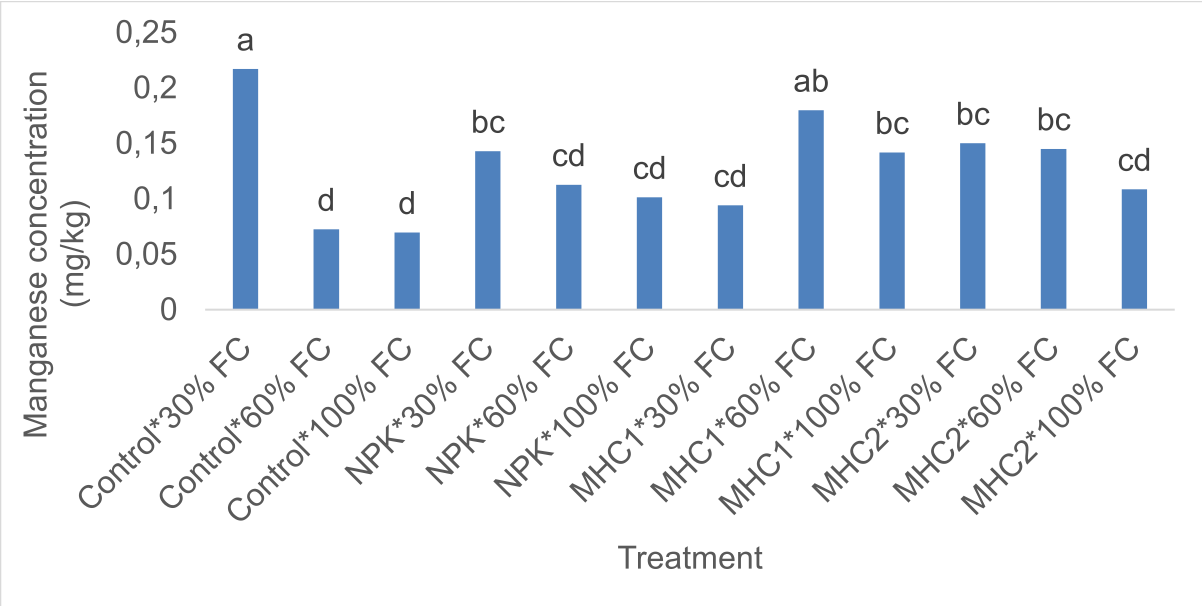

Figure 41. Response of manganese to fertilizer and different water regimes

Moderate irrigation, at 60% FC and 30 t ha^{-1} MHC increased concentration of K (Figure 42) and Zn (Fig 6) by 96% and 63%, respectively. 30% FC and control increased nutrient concentration of Mn in jute mallow leaves by 66%, whereas NPK at 100% FC decreased concentration of Mn by 78%.

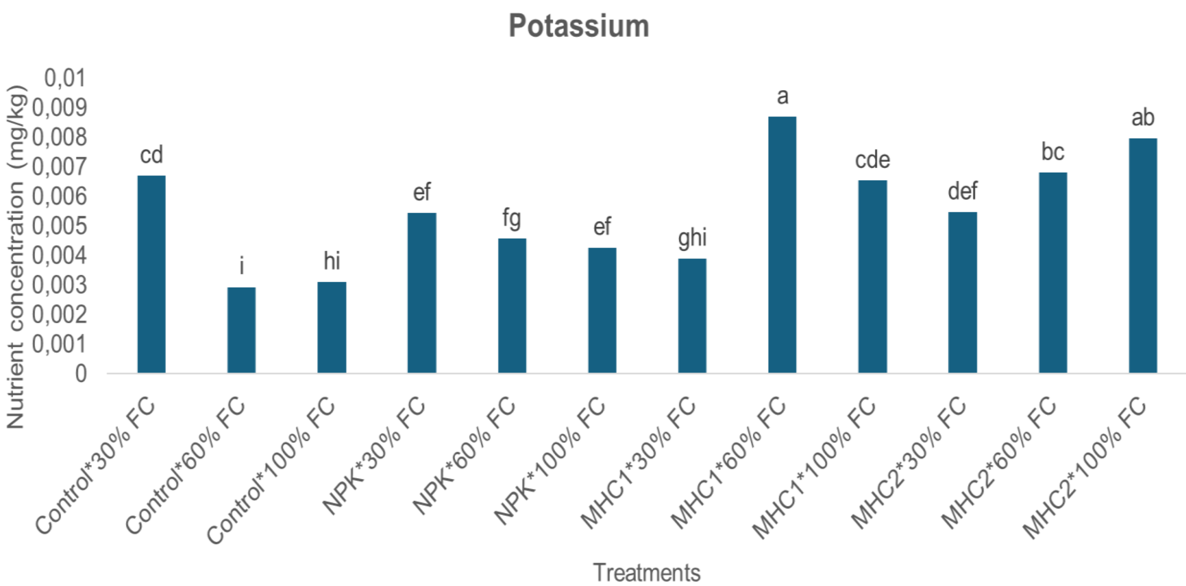

Figure 42. Response of potassium to fertilizer and water regimes.

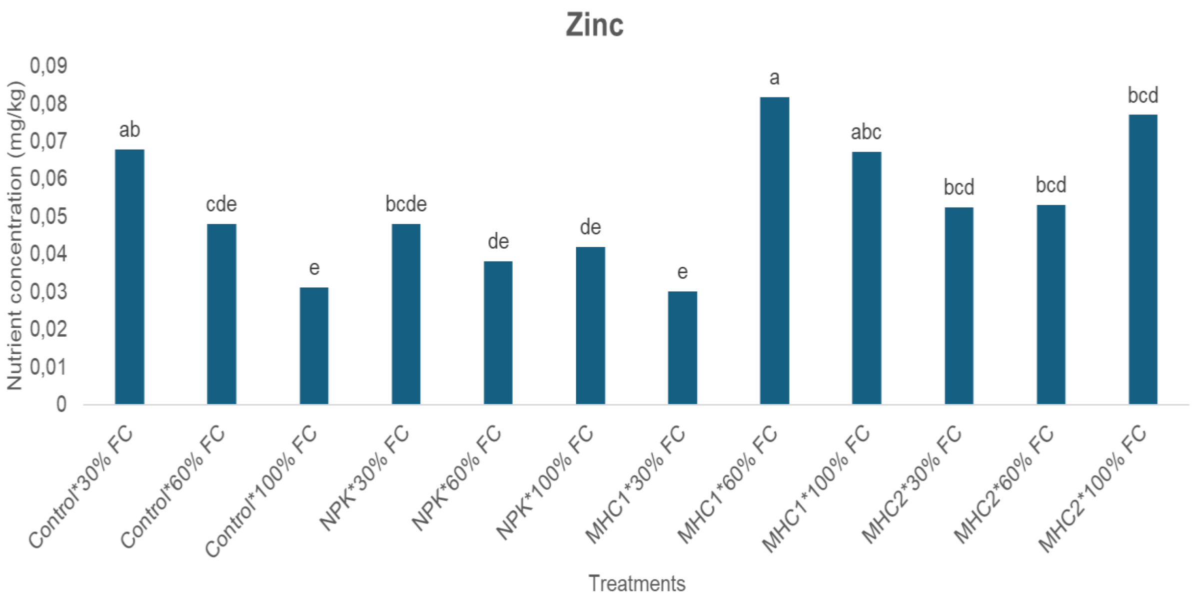

Figure 43. Response of zinc to fertilizer treatments and water regimes.

4.3.3 Response of jute mallow's phytochemicals to macadamia husk compost and water regimes

The response of jute mallow's phytochemicals to macadamia husk compost and water regimes is presented in Table 17 below. The fertilizer and irrigation treatments did not have significant effect on DPPH assays. However, fertilizer treatments had a significant effect on FRAP assay, total flavonoid, and moisture content at P<0.05 (Table 17). It was shown that 30 t ha^{-1} MHC increased FRAP assay, and total flavonoid by 20% (3.076 vs 2.448 uM), and 19% (11.83 vs 9.63 ug/ml), respectively, without any significant difference from 60 t ha^{-1} MHC. In addition, NPK was not significantly different to 60 t ha^{-1} MHC on total flavonoid contents of jute mallow, and it increased the flavonoid content by 9% (10.55 vs 9.63 ug/ml). However, 60 t ha^{-1} MHC decreased moisture content of jute mallow by 81% (40.85 vs 7.59 %), whereas 30 t ha^{-1} MHC decreased by 80% (40.85 vs 8.12%). In recent studies, organic fertilization significantly improves antioxidant capacity and phytochemical contents in leafy vegetables and the medicinal plant *Labisia pumila*, enhancing total phenolics, flavonoids, and ascorbic acid compared to conventional fertilization.

Irrigation treatments had a significant effect on FRAP assay, total flavonoid content (TFC), total phenolic content (TPC), and moisture (Table 17). However, applying water at 60% FC, decreased jute mallow FRAP assay by 16% (3.302 vs 2.788 uM), whereas irrigation at 30% decreased FRAP by 27% (3.302 vs 2.418 uM), relative to the control. Moreover, relative to the control, irrigation at 30% FC decreased moisture and total flavonoid content by 57% (29.27 vs 12.64%), and 29% (11.46 vs 8.12 ug/ml), respectively (Table 17). However, this was contradictory to a study on medicinal plants, where water-deficit (moderate water stress) resulted on slight increase on phenolic content and leaf flavonoids, though under severe drought results were not uniform. This highlights that not all species respond in a similar way to water stress.

Interaction of fertilizer and irrigation treatments had a significant impact on FRAP, TFC, TPC, and moisture content at $p<0.001$ (Table 17). Relative to the control, 60 t ha^{-1} MHC*100% FC increased FRAP, TFC, and TPC by 25% (4.874 vs 3.641 Um), 56% (17.77 vs 7.74 ug/ml), and 66% (18.27 vs 6.30 ug/ml), respectively. Moreover, 30 t ha^{-1} MHC* 30% FC interaction increased TPC, TFC, and FRAP by 63% (6.30 vs 16.95 ug/ml), 2% (7.74 vs 7.91 ug/ml), and 19% (3.641 vs 4.479 uM), respectively relative to the control. However, relative to the control, the moisture content was decreased by NPK*30% FC, 30 t ha^{-1} MHC* 30% FC, and 60 t ha^{-1} MHC* 30% FC interactions by 52% (27.59 vs 56.94%), 85% (8.46 vs 56.94%), and 87% (7.22 vs 56.94%), respectively.

Table 17: Effect of macadamia husk compost and water regimes on phytochemicals of jute mallow

Treatments	DPPH (%)	FRAP (uM)	TFC (ug/ml)	TPC (ug/ml)	ASH (%)	Moisture (%)
Fertilizers						
Control	44.9 a	2.448 b	9.63 b	10.13 a	13.59 a	40.85 a
NPK	34.2 a	2.575 b	10.55ab	9.23 a	13.39 a	38.73 a
30 t ha^{-1} MHC	54.3 a	3.076 a	11.83 a	10.15 a	13.64 a	8.12 b
60 t ha^{-1} MHC	39.0 a	3.247 a	10.61ab	10.71 a	13.25 a	7.59 b
L.s.d	14.65	0.3207	1.303	2.877	4.083	24.386
Irrigation						
30% FC	45.4 a	2.418 c	8.12 b	11.69 a	13.13 a	12.64 b
60% FC	41.5 a	2.788 b	12.38 a	8.81 b	13.70 a	29.55 a
100% FC	42.4 a	3.302 a	11.46 a	9.66 b	13.58 a	29.27 a
L.s.d	6.84	0.1483	1.101	1.889	2.225	3.024
Fertilizers*Irrigation						
Control*30% FC	46.0 a	1.836 f	10.06 bc	15.18 ab	13.28 a	7.30 b
Control*60% FC	38.9 a	1.866 f	11.08 b	8.91 c	13.44 a	58.29 a
Control*100% FC	49.9 a	3.641 c	7.74 defg	6.30 c	14.05 a	56.94 a
NPK*30% FC	28.7 a	1.986 f	8.54 cd	7.46 c	13.01 a	27.59 b
NPK*60% FC	36.4 a	2.480 e	11.37 b	12.62 b	15.04 a	44.87 a
NPK*100% FC	37.6 a	3.261 d	11.75 b	7.61 c	12.11a	43.74 a
30 t ha-^{1} MHC* 30% FC	63.3 a	4.479 b	7.91 def	16.95 a	13.46 a	8.46 b
30 t ha-^{1} MHC* 60% FC	47.5 a	3.315cd	18.98 a	7.04 c	13.39 a	7.64 b
30 t ha-^{1} MHC* 100% FC	52.0 a	1.434 g	8.59 cd	6.46 c	14.08 a	8.25 b
60 t ha^{-1} MHC*30% FC	43.6 a	1.374 g	5.96 eg	7.19 c	12.78 a	7.22 b
60 t ha^{-1} MHC*60% FC	43.1 a	3.493 cd	8.11 de	6.68 c	12.92 a	7.40 b
60 t ha^{-1} MHC*100% FC	30.1 a	4.874 a	17.77 a	18.27 a	14.06 a	8.13 b
L.s.d	15.09	0.3290	1.942	3.557	4.517	23.458
F- Statistics						
Fertilizer	448.40 ns	0.890 *	4.876 *	2.260 ns	0.196 ns	2044.903 *
Irrigation	33.38 ns	1.576***	40.277 ***	17.554 *	0.715 ns	749.808 ***
Fertilizer*Irrigation	107.92 ns	4.11 0***	42.593 ***	65.557 ***	1.802 ns	375.568 ***
CV (%)	13.8	4.5	9.0	16.3	14.3	11.0

***; **; * = significant at the 0.1%, 1% and 5% probability level respectively. Means with the same letters are not significantly different

4.3.4 Effects of macadamia husk compost and water regimes on soil quality

Soil pH water was highly significant in 2023/2024 season in response to 60 t ha^{-1} MHC*60% FC, and NPK*100% FC interaction (Table 18). Relative to control*100% FC, interaction between fertilizer and water regimes interactions decreased soil resistance in both seasons (Table 18). However, the soil resistance decreased in 2024/2025 compared to the 2023/2024 control by 47% (2700 vs 1440 ohms). Furthermore, relative to the control, 60 t ha^{-1} MHC*60% FC interaction in 2024/2025 significantly increased Ca, Mg, C, and organic matter by 28% (1110.0 vs 803.0 g kg^{-1}), 31% (279.0 vs 192.0 g kg^{-1}), 12% (1.440 vs 1.270%), and 11% (2.468 vs 2.186%), respectively. Similarly, 60 t ha^{-1} MHC*30% FC increased Ca, Mg, K, Na, C, and organic matter in 2023/2024 season by 36% (878 vs 565.5), 36% (222.0 vs 143.0 g kg^{-1}), 49% (257.5 vs 130.5 g kg^{-1}), 40% (21.50 vs 13.00 g kg^{-1}), 20% (1.275 vs 1.026%), and 19% (2.188 vs 1.762%) respectively, relative to the control. In 2023/2024 growing season, NPK*60% FC increased P in the soil by 29% (7.965 vs 5.620 g kg^{-1}), while in 2024/2025 P was increased by 30 t ha-^{1} MHC* 60% FC with 3% (7.315 vs 7.130 g kg^{-1}), relative to the control (Table 18).

Table 18: Effects of macadamia husk compost and water regimes on soil qualities for two growing seasons.

Season	Treatments	pH	Res (Ohms)	Ca	Mg	K g kg-1	Na	P	C	Organic matter (%)
2023/2024	Control*30% FC	6.22 bcd	2000 d	594.0 p	148.0 o	171.0 l	30.50 c	5.390 no	0.734 k	1.269 l
2023/2024	Control*60% FC	5.93 efg	1900 e	728.0 k	178.0 l	190.0 f	20.50 ef	5.950 ij	1.107 g	1.903 h
2023/2024	Control*100% FC	6.230 bc	2700 a	565.5 q	143.0 p	130.5 p	13.00 k	5.620 l	1.026 h	1.762 i
2023/2024	NPK*30% FC	6.230 bc	2260 b	652.0 o	162.0 n	186.0 ghi	13.00 k	7.490 c	0.740 k	1.270 l
2023/2024	NPK*60% FC	6.255 b	2100 c	569.0 q	145.5 op	148.5 n	16.50 hij	7.965 a	0.830 j	1.411 k
2023/2024	NPK*100% FC	6.360 a	1920 e	703.0 m	175.5 lm	186.5 fghi	18.00 gh	7.700 b	1.192 f	2.046 g
2023/2024	30 t ha-1 MHC* 30% FC	6.010 e	1600 ij	864.5 c	159.5 n	143.0 o	12.50 k	5.670 l	0.863 i	1.481 j
2023/2024	30 t ha-1 MHC* 60% FC	6.190 bcd	2000 d	679.5 n	173.5 m	195.0 e	24.50 d	5.925 ij	1.191 f	2.050 f
2023/2024	30t ha-1 MHC* 100% FC	6.240 bc	1740 gh	775.0 j	197.5 h	199.5 d	17.00 hi	6.085 h	1.030 h	1.764 i
2023/2024	60 t ha-1 MHC*30% FC	6.130 d	2000 d	878.0 b	222.0 b	257.5 a	21.50 e	4.970 p	1.275 d	2.188 d
2023/2024	60 t ha-1 MHC*60% FC	6.390 a	1840 f	698.0 m	183.5 k	220.0 c	15.00 j	5.610 l	1.235 e	2.116 e
2023/2024	60 t ha-1 MHC*100% FC	6.145 cd	1700 h	730.0 k	191.0 j	220.0 c	18.00 gh	5.650 l	1.314 c	2.258 c
2024/2025	Control*30% FC	5.830 h	1560 jk	821.0 f	203.0 g	184.5 hi	17.50 h	5.990 i	0.822 j	1.411 k
2024/2025	Control*60% FC	5.820 h	1600 ij	795.5 i	207.5 f	172.0 kl	20.00 ef	6.540 f	1.187 f	2.045 g
2024/2025	Control*100% FC	5.940 efg	1440 l	803.0 h	192.0 ij	159.5 m	20.50 ef	7.130 e	1.270 d	2.186 d
2024/2025	NPK*30% FC	5.815 h	1560 jk	772.5 j	194.5 i	175.0 jk	15.50 ij	5.760 k	1.273 d	2.186 d
2024/2025	NPK*60% FC	5.955 ef	1750 g	808.0 h	190.5 j	176.0 j	18.00 gh	5.980 i	1.026 h	1.763 i
2024/2025	NPK*100% FC	5.855 gh	2065 c	717.5 l	177.5 l	147.0 n	18.00 gh	5.890 j	1.190 f	2.045 g
2024/2025	30 t ha-1 MHC* 30% FC	5.950 efg	1705 gh	842.5 d	210.5 e	187.5 fgh	23.50 d	5.440 mn	1.272 d	2.186 d
2024/2025	30 t ha-1 MHC* 60% FC	5.910 fgh	1825 f	863.5 c	218.0 c	183.5 i	19.50 fg	7.315 d	1.272 d	2.186 d
2024/2025	30 t ha-1 MHC* 100% FC	5.880 fgh	1550 k	867.5 c	213.5 d	189.0 fg	17.00 hi	5.925 ij	1.273 d	2.186 d
2024/2025	60 t ha-1 MHC*30% FC	5.820 h	1610 i	831.5 e	213.0 de	196.5 de	42.50 a	6.190 g	1.354 b	2.327 b
2024/2025	60 t ha-1 MHC*60% FC	5.700 i	1280 m	1110.0 a	279.0 a	234.0 b	33.50 b	5.490 m	1.440 a	2.468 a
2024/2025	60 t ha-1 MHC*100% FC	5.910 fgh	1985 d	814.0 g	190.0 j	178.0 j	23.50 d	5.355 o	1.112 g	1.904 h
	L.s.d	0.09774	48.79	5.473	2.552	3.898	1.830	0.08372	0.0084	0.0034
	CV (%)	0.8	1.3	0.3	0.6	1.0	4.3	0.7	0.4	0.1

4.4. DISCUSSION

4.4.1. Growth and yield of jute mallow in response to macadamia husk compost and water regimes

The significant impact of fertiliser amendments on the number of branches per plant and chlorophyll content of jute mallow at the vegetative stage (49 DAT) across both cropping seasons is consistent with reports on traditional leafy vegetables (TLVs), which are known to respond strongly to nutrient availability during early growth. The amendment of MHC at 60 t ha^{-1} decreased chlorophyll content in jute mallow leaves. Similarly, Radziah et al. (2009) reported that Polianthes tuberose L. plants treated with organic fertiliser (Thank-Q) had lower chlorophyll content than those treated with inorganic fertiliser (BBSCKAB). Similar to the results, Ikyo et al. (2020) reported variation in chlorophyll content between organic (pig manure) and inorganic (NPK, urea) fertilisers in amaranth and jute mallow, with organic fertiliser resulting in lower chlorophyll content compared to inorganic nitrogen sources, thereby emphasising the importance of balanced nutrient release to crop demand. Wu et al. (2024) indicated that high rates of organic fertilisers without balanced nutrient supplementation can reduce chlorophyll and photosynthetic performance when essential nutrients are not sufficiently available or are immobilised by high carbon inputs, resulting in reduced pigment synthesis and photosynthetic capacity at key developmental stages. Conversely, Kece et al. (2024) indicated that organic fertiliser, like solid worm manure, increased chlorophyll content in lettuce leaves.

Although NPK showed a significant elevation in the number of branches per plant in 2023/2024, in the 2024/2025 cropping season, treatment of 30 t ha^{-1} MHC produced a high number of branches per plant at 49 days after planting. Olorukooba et al. (2020) indicated that organic fertilisers, such as poultry manure, increased the number of branches in jute mallow plants. Moreover, a study in Benin showed that organic manures, such as municipal solid waste compost and cow dung, positively influenced the number of branches per plant of jute mallow at 6 weeks after transplanting (Tovihoudji et al., 2015). Macadamia husk compost increased the number of branches per plant more than NPK fertiliser in the 2024/2025 cropping season, and this was attributed to the ability of organic manure to improve moisture retention and environmental stress mitigation, thereby providing an advantage over inorganic fertilisers under adverse climatic conditions (Bot & Benites, 2005). The observed response under NPK treatment is likely due to the rapid supply of soil nutrients, particularly nitrogen, which promotes early vegetative growth and lateral branching when environmental conditions support efficient nutrient uptake (Marschner, 2012; Fageria et al., 2011). In addition, the absence of substantial distinctions between MHC rates may reflect enhanced soil physical qualities, including improved water retention capacity and reduced bulk density occurring across all compost treated soils, thereby creating similar root growth conditions regardless of application rate (Maselesele et al., 2021).

Under deficit irrigation conditions, nutrient uptake efficiency can be constrained regardless of soil nutrient abundance, thereby reducing the observable differences in yield response to fertiliser rates

(Singh et al., 2021; Maseko et al., 2020). A field study on *Amaranthus hybridus* showed that fertilisers, either organic (kraal manure) or inorganic (NPK), significantly increased vegetative growth parameters (number of leaves, shoot mass) compared with the control (Kunene et al., 2019). In contrast to our findings, kraal manure and NPK treatments had no variation in many growth parameters, such as plant height, number of leaves per plant, and amaranth yield (Kunene et al., 2019).

Macadamia husk compost at 30 and 60 tha^{-1} produced plants with higher plant height at vegetative and reproductive stages during the 2024/2025 cropping season. Hoang et al. (2021) reported that the application of well-prepared organic compost, resulted in greater plant height and leaf production than low- or no-fertiliser treatments in spinach, amaranth, and mustard greens, reflecting enhanced vegetative vigour under organic nutrient inputs. A study on amaranth reported that the application of organic fertilisers promoted plant height and vegetative growth (Kunene et al., 2019). During the 2024/2025 season, stem diameter was highest at 49 DAT with applications of 30 and 60 tha^{-1} MHC compared to inorganic fertiliser (NPK) and the control. Studies on TLVs have shown that repeated or residual application of organic amendments can enhance vegetative traits, including branch number, more effectively than inorganic fertilisers in later seasons (Nyathi et al., 2018; Ochieng et al., 2021). The observed increases in chlorophyll content under fertiliser application across both seasons further support these findings.

The significant effects of irrigation treatments on the number of branches per plant, plant height, stem diameter, and chlorophyll content at 49 days after transplanting (DAT) during the 2023/2024 growing season demonstrated the sensitivity of Indigenous leafy vegetables (ILVs), including jute mallow (*Corchorus olitorius*), to soil moisture availability during early vegetative growth. The reduction in the number of branches per plant and plant height under deficit irrigation at 30% FC indicated that water stress constrained cell expansion, apical dominance, and axillary bud development, as water deficit reduces turgor-driven cell elongation and alters hormonal regulation of shoot growth (Farooq et al., 2009; Mabhaudhi & Modi, 2015; Taiz et al., 2015). Similar responses have been reported in indigenous leafy vegetables under moisture stress, in which vegetative growth is highly sensitive to soil water availability (Farooq et al., 2009; Mabhaudhi & Modi, 2015; Mabhaudhi et al., 2016). Furthermore, similar reductions in vegetative growth under water deficit have been reported in jute mallow, amaranth (*Amaranthus spp.*), and African nightshade (*Solanum scabrum*), where insufficient soil moisture limits nutrient transport, reduces turgor pressure, and suppresses shoot growth (Mabhaudhi & Modi, 2015; Nyathi et al., 2018). Increased chlorophyll content under water stress has been reported in several leafy vegetables, such as Amaranthus spp. and spinach (Spinacia oleracea), and is often associated to a concentration effect resulting from reduced leaf expansion rather than increased chlorophyll synthesis (Anjum et al., 2011; Ochieng et al., 2019). These results showed that water stress enhanced chlorophyll content in jute mallow. However, Cheboi et al. (2024) reported a reduction in chlorophyll content in pigeon pea genotypes under water stress conditions.

The observed responses support the potential of deficit irrigation strategies for traditional leafy vegetable production in water-limited environments, when climatic conditions and soil moisture are adequately managed. Therefore, these findings are particularly relevant for smallholder farmers, who face limited water resources and increasing climate variability. The results suggested that well-watered treatments support optimal production of jute mallow plants. In contrast, irrigation treatments had no significant effects on stem diameter, plant height, number of branches, or chlorophyll content at 77 days after planting in the 2024/2025 season. This further reinforces the role of favourable climatic conditions, such as adequate rainfall and moderate temperatures, in buffering the effects of deficit irrigation at later growth stages.

These results indicated that jute mallow, like other TLVs, exhibits a degree of physiological adaptability, enabling it to tolerate moderate water limitation while maintaining productivity. Similar to the study, water stress was reported to reduce fresh and dry biomass of African nightshade, amaranth, and spider plant, highlighting the sensitivity of TLVs to soil moisture availability (Mabhaudhi et al., 2016; Ochieng et al., 2019). The combined effects of irrigation and fertiliser were evident during the first harvest at 35 DAT, where 60 t ha^{-1} MHC under full irrigation at 100% FC significantly increased fresh biomass by 21% compared to the control. Similarly, 30 t ha^{-1} MHC under 60% FC maintained leaf biomass, whereas 30 t ha^{-1} MHC under 30% FC decreased yield. This demonstrated that adequate soil moisture enhanced the effectiveness of organic fertilisers, whereas severe water deficits can limit nutrient uptake and reduce yield, as observed in African leafy vegetables and other TLVs (Mabhaudhi & Modi, 2015; Ochieng et al., 2019). The results indicated that water availability is the dominant factor in early leaf production, with fertiliser benefits most pronounced under sufficient soil moisture.

4.4.2 Response of leaf nutrient concentration to macadamia husk compost and water regimes

In this study, MHC increased the leaf nutrient content of Jute mallow. Application of 30 and 60 t ha^{-1} MHC improved leaf nutrient content P, K, Ca, Mg, S, Zn, Cu, Mn, Fe, and B compared to the control and NPK fertilisers. The observed increase in K, P, Mg, B, Mn, Zn, Cu, and Ca content when MHC was applied was similar to the increase in mineral content reported in mustard spinach treated with MHC (Maselesele et al., 2022). It was also reported that organic amendments can supply a broader spectrum of macro- and micronutrients to leafy vegetables, leading to enhanced uptake synergies among nutrients such as N, P, K, Mg, and trace elements like Zn, Mn, and Fe, thereby supporting improved nutritional quality and metabolic activity in plant tissues (Nhamo, 2001; Scotti et al., 2015; Ayamba et al., 2023). These findings align with Mofunanya et al. (2015), who reported that organic fertilisers such as sawdust, poultry droppings, and cow dung increased Mg, Zn, Cu, K, Fe, Ca, Na, and P in the leaves of *Amaranthus spinosus* compared to NPK Fertiliser. Uusiku et al. (2010) reported that organic fertilisers improved soil nutrients and soil pH, thereby influencing micronutrient content in African leafy vegetables. The limited influence of irrigation on the nutritional composition of jute mallow indicated that the fertiliser treatments could mitigate the crop’s nutrient content against water stress. Moreover, adequate soil moisture improved nutrient content in jute mallow leaves, but water stress can limit the uptake of essential mineral cations by plant roots (Tovihoudji et al., 2015; Adediran et al., 2024). Irrigation treatments did not affect the nutritional content of jute mallow in the present study.

4.4.3 Response of jute mallow's phytochemicals to macadamia husk compost and water regimes

Fertiliser treatments influenced antioxidant capacity, TFC, and moisture content of jute mallow. Application of 30 and 60t ha^{-1} MHC increased the antioxidant capacity, TFC, and moisture content of jute mallow. This may be attributed to MHC's ability to improve soil health, leading to the production of secondary metabolites and enhanced plant health and biochemical processes, thereby simultaneously increasing the accumulation of flavonoids and other antioxidants in plant tissues (Rusli et al., 2022). Organic manure significantly increased antioxidant activity (FRAP), TPC and TFC in fenugreek seeds (Salehi et al., 2019). Moreover, chicken and horse manure significantly increased TPC in Brassicaceae vegetables compared to the control (Antonious, 2023). Similarly, application of organic manure in *Labisia pumila* enhanced total phenolics and flavonoids relative to inorganic fertiliser, suggesting that organic sources promote phytochemical synthesis (Ibrahim et al., 2013). Similar to the study, poultry manure and NPK fertiliser had no significant effect on the ash content of jute mallow leaves (Adediran et al., 2024). Organic fertilisers, such as macadamia husk compost (MHC), are known to enhance soil nutrient retention and microbial activity, which promotes gradual nutrient release and improved nutrient use efficiency (Cox et al., 2004; Maselesele et al., 2021). The observed increase in ferric reducing antioxidant power (FRAP) in jute mallow plants treated with macadamia husk compost (MHC) at both 30 and 60 t ha^{-1} indicated that organic amendments improved the antioxidant capacity compared with the control and NPK fertiliser. This aligns with Cavalheiro et al. (2020) study, which demonstrated that fruit and vegetable residues compost increased antioxidant capacity when using FRAP, ORAC, Folin, and ABTS in lettuce. Similar results were reported by Ivanović et al. (2018) in Swiss chard. In addition, the current study showed that deficit irrigation increased the total phenolic content of jute mallow. Similarly, Anim et al. (2025) reported that deficit irrigation increased TPC in fruits and vegetables. Deficient irrigation decreased TFC and soil moisture of jute mallow, while moderate irrigation increased the TFC and moisture content. Similarly, Sarker and Oba, (2018) reported that occasional moderate irrigation increased TFC in *Amaranthus tricolor*, however, it reduced antioxidant activity and TFC under deficit irrigation.

4.4.4 Effects of macadamia husk compost and water regimes on soil quality

The current study demonstrated an increase in soil nutrients such as N, P, K, Ca, and Mg under moderate irrigation at 60% FC in both seasons, could be attributed to improved microbial activity and organic matter mineralisation under favourable moisture conditions as previously reported (Paul, 2015;

Schimel, 2018). In this study, during the 2023/2024 cropping season, irrigation treatments did not influence the soil organic carbon (SOC). According to Six et al. (2002), significant effects of compost on soil carbon may take extended periods to be observed in the soil. However, the recorded low soil organic matter (SOM) under 60% FC during the 2023/2024 season supports the previous reports that well-irrigated areas result in rapid decomposition and organic matter turnover (Bronson et al., 2004; Lal, 2015).

Macadamia husk compost elevated soil pH and SOC, and this was similar to those reported on filter cake and poultry manure in maize (Mokolobate & Haynes, 2002). The significant increase in soil pH under MHC application, especially at 60 t ha^{-1} can be attributed to the addition of basic cations such as Ca^{2+} and Mg^{2+}, which neutralise soil acidity through exchange reactions (Haynes & Mokolobate, 2001). Similarly, it was reported that the application of MHC and NPK fertiliser can improve the soil pH values (Maselesele et al., 2021). Organic fertilizersare reported to buffer soil pH by increasing cation exchange capacity and reducing Al^{3+} activity in acidic soils (Walker & Bernal, 2008). Soil Ca and Mg content under both 30 and 60 t ha^{-1} MHC were higher, which highlights that organic composts are important sources of exchangeable base cations. In the present study, soil chemical properties such as N, Na, P, K, Ca, and Mg increased under MHC application, and these findings align with numerous studies demonstrating the benefits of organic composts in enhancing soil quality through nutrient addition, buffering capacity, and organic matter enrichment (Agegnehu et al., 2016; Adekiya et al., 2020). Fatokun et al. (2023) demonstrated that MHC increased total N and C, indicating a high C:N ratio and high mineralisation of C in the soil.

Potassium availability was higher at the 60 t ha^{-1} MHC application rate, indicating a relatively rapid release of K from decomposing organic residues (Marschner, 2012; Adekiya et al., 2020). However, lower P levels in soils under 60 t ha^{-1} MHC in all irrigation treatments are likely attributed to P immobilisation within organic complexes or fixation by Ca and Fe compounds released from the compost (Hinsinger, 2001). Similarly, low levels in available P following high organic amendment rates have been reported in compost-amended soils, especially where organic inputs are rich in polyvalent cations (Walker & Bernal, 2008). Macadamia husk compost application significantly increased SOC, total N, and P content, as supported by an earlier study (Maselesele et al., 2021). Furthermore, SOC and SOM were high under 60 t ha^{-1} of MHC, which indicated that organic compost significantly contributed to soil carbon sequestration and structural stability, and improved microbial activity (Agegnehu et al., 2014).

Irrigation regime significantly influenced nutrient distribution, with moderate irrigation at 60% FC generally promoting higher nutrient availability than severe deficit or full irrigation. Therefore, this agrees with previous reports that moderate soil moisture optimises microbial mineralisation while minimising nutrient leaching and salt accumulation (He et al., 2015). However, the observed low soil pH under deficit irrigation suggested an increased acidification, potentially due to reduced buffering capacity and the accumulation of acidic ions in the soil solution (Farooq et al., 2009). Additionally, moderate irrigation at 60% FC generally enhanced soil nutrients such as N, P, K, Ca, and Mg, likely due to improved microbial activity and organic matter mineralisation under favourable moisture conditions (Paul, 2015; Schimel, 2018). The significant influence of irrigation treatments on soil resistance, SOC, SOM, and macronutrients (Ca, Mg, P, K, N, and Na) at $p < 0.001$ indicated a strong role for soil moisture in regulating soil chemical availability and electrochemical properties. Similarly, soil moisture content influences nutrient availability and microbial activity, thereby improving soil fertility (Hillel, 2004; Lal, 2015). Furthermore, the elevated Ca, Mg, and K levels under 60 t ha^{-1} MHC at 60% FC demonstrated the benefits of organic fertiliser and optimal moisture conditions, as the organic amendments are known to improve cation exchange capacity (CEC), nutrient retention and reduce leaching losses (Agegnehu et al., 2016; Lehmann & Kleber, 2015).

Low SOM and SOC under deficit irrigation at 30% FC may be related to limited microbial activity under water stress (Blanco-Canqui et al., 2017). Therefore, these results indicate that irrigation treatments can significantly affect root growth in the crop. Moreover, the lower root biomass under full irrigation compared to under low irrigation can be attributed to jute mallow's shallow root system and its sensitivity to water stress (Maseko et al., 2020). These findings show that MHC had the ability to sustain the growth and performance of jute mallow plants by improving the crop's root system. Ray et al. (2025) indicated that organic fertilizers such as chicken and dairy manure increased the root density of *Brassica oleracea.* Organic amendments such as MHC, chicken and dairy manure improved SOC, SOM, and soil nutrient content, therefore resulting in enhanced root biomass (Maselesele et al., 2021; Ray et al., 2025).

4.5. CONCLUSSION

Macadamia husk compost significantly enhanced both macro- and micronutrient content when compared with the control and NPK fertiliser. Macadamia husk compost improved phosphorus, potassium, magnesium, calcium, sulphur, zinc, copper, manganese, iron, and boron content. The MHC application rates of 30 and 60 t ha^{-1} did not show any differences in the nutritional content of jute mallow, indicating that nutrient uptake reached an optimum at the lower application rate and there is no need to apply a higher rate. In contrast, NPK fertilisation was ineffective, particularly for micronutrient enrichment. Moreover, the study showed that irrigation treatments influenced antioxidant capacity, as estimated by FRAP, TPC, TFC, and moisture content in jute mallow. Therefore, it can be concluded that macadamia husk compost is an effective and sustainable fertiliser for improving the nutritional content and antioxidant capacity of jute mallow, while moderate compost application rates are sufficient to achieve optimal results. These findings support the integration of organic fertilisation strategies into jute mallow production systems, particularly under variable water availability.

The study demonstrated that MHC improved soil chemical properties by enhancing organic matter and carbon content. Moreover, the interaction between irrigation treatments and MHC offered a viable strategy to improve soil fertility, nutrient retention, and long-term sustainability in degraded agricultural systems. Moderate irrigation at 60% FC combined with MHC at 60 t ha^{-1}, optimised soil chemical properties, enhanced nutrient retention, and improved soil electrochemical properties. These findings highlight the necessity of interacting irrigation and organic amendments for sustaining soil fertility under water-limited conditions, especially for smallholder and organic production systems. The application of MHC enhanced soil nutrient status and strengthened positive interactions among key soil properties, as evidenced by strong correlations between Ca, Mg, K, SOC, SOM, and nitrogen across both cropping seasons. These relationships enhanced cation exchange capacity and improved nutrient synchrony in soils treated with MHC. Moreover, application of NPK fertiliser under full irrigation was less effective in improving SOM and SOC, presenting a limited effect on long-term soil quality.

The research demonstrated that the utilization of macadamia husk compost (30 and 60 t ha^{-1}) improved the number of branches per plant, plant height, and stem diameter. Therefore, MHC can serve as an alternative to improve jute mallow growth parameters for resource-poor farmers and for sustainable crop production. Thus, to achieve maximum yield and growth, a lower rate of MHC (30 t ha^{-1}) can be used, since higher application of MHC (60 t ha^{-1}) produced similar yields and improved growth. The study also found that the application of NPK fertiliser improved the chlorophyll content. Furthermore, irrigation regimes influenced stem diameter, plant height, number of branches per plant and chlorophyll content 49 DAT in the 2023/2024 cropping season. The highest chlorophyll content was observed under deficit irrigation at 30% FC, while the same treatment decreased plant height, stem diameter, and number of branches per plant in the 2023.2024 cropping season. In addition, moderate irrigation at 60% FC and control at 100% FC increased the number of branches per plant, plant height, and chlorophyll content, indicating that moderate irrigation yielded the same response as 100% FC. Therefore, the study concluded that water availability is the primary factor influencing vegetative growth and yield of jute mallow, while organic fertilisation improved biomass accumulation under adequate moisture conditions. These findings provided practical guidance for the sustainable production of TLVs in water-limited environments, promoting food security and efficient use of organic amendments. Further research is required to assess the long-term effects of these treatments on nutrient uptake and yield under varying environmental conditions with different indigenous leafy vegetables.

CHAPTER 5: GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This project was designated to conserve indigenous knowledge on traditional leafy vegetables and to assess their importance in poverty alleviation and water conservation. The project selected four major objectives as a measure to achieve the aim of the project.

Objective one focused on reviewing the literature available about the consumption, production and selling or commercialisation of traditional leafy vegetables. The review study revealed that there is plenty of indigenous knowledge available on traditional leafy vegetables. However, there is a sign of the disappearance of this knowledge, partly due to globalisation, urbanisation, modernisation, and the stigma that traditional leafy vegetables represent poverty. The study concluded that people in rural and peri-urban areas consume traditional leafy vegetables, while a few sell them to earn income. However, there is a gap in the production of traditional leafy vegetables, partly due to a lack of in-depth research by various institutions and a lack of agronomic information about the traditional leafy vegetables. The review also identified the most utilised traditional leafy vegetable in the study area.

Objectives two and three were designated to identify factors that affect the production, consumption and selling of traditional leafy vegetables. It also studied the nutritional and medicinal values of traditional leafy vegetables. People were able to identify several traditional leafy vegetables that they consume the most and those with economic value. The nutritional and medicinal benefits of traditional vegetables were listed. Lack of resources, climate change, and lack of government support were listed by most respondents as the main factors limiting the production, consumption, and sale/commercialisation of traditional leafy vegetables. There is evidence that people process and preserve traditional vegetables to increase shelf life, improve quality, and use them during the drought period. There is an increase in the sale and commercialisation of traditional vegetables in both formal and informal markets, aimed at generating income.

Objective four focussed on the effects of water regimes and macadamia husk compost on traditional leafy vegetables with specific to Jute mallow. The study revealed that macadamia husk compost (MHC) significantly enhances soil chemical properties and the nutritional quality of jute mallow. Application rates of 30 t ha^{-1} and 60 t ha^{-1} both improved soil nutrients, plant growth and yield, with 30 t ha^{-1} MHC often matching the benefits of 60 t ha^{-1} MHC. This improvement led to increased antioxidant activity and flavonoid content in jute mallow, indicating a saturation effect where moderate amendment is adequate. Although NPK also improved flavonoid levels, its effect was less notable compared to MHC, suggesting organic amendments enhance soil biological activity. Conversely, reduced irrigation negatively affected plant quality by lowering antioxidant levels. The findings emphasize integrating organic amendments such as macadamia husk compost with optimal moisture levels for better soil health and nutritional quality in jute mallow, highlighting 30 t ha^{-1} MHC as an efficient choice for sustainable leafy vegetable production.

5.2. RECOMMENDATIONS

In light of the above, it was recommended that agricultural policies include strategies to encourage the cultivation and consumption of traditional leaf vegetables. The government should create and implement programs to support the cultivation of traditional leafy vegetables by rural and semi-rural communities.

The importance of traditional leafy vegetables must be recognised and promoted to increase their production and consumption. Providing water in the Vhembe district can encourage farmers to produce and sell traditional leafy vegetables. If the potential of traditional leafy vegetable crop production is realised for large-scale commercial ventures, further financial investment would follow, and the involvement of a younger, entrepreneurial generation would be developed.

The health and nutritional values of traditional vegetables must be scientifically proven rather than merely myth, which calls for a robust investigation. The establishment of pharmaceutical company in the Vhembe district is recommended. Such an initiative could lead to the production of traditional leafy vegetables on a large, intensive scale.

Government and private institutions must support or fund research projects that focus on the cultivation practices, planting and harvesting methods, and optimal water and fertilizer requirements. The study recommends that research institutions, Non-profit organisations, academic institutions, and policymakers collaborate to ensure the integration of traditional leafy vegetables into food systems.

There is need to enhance awareness campaigns to educate people about the importance of traditional leafy vegetables and their potential in alleviating poverty. Public awareness regarding the cultivation, consumption, and sale of traditional leafy vegetables must be created.

There is a need to conduct a detailed study of the water-use efficiency of the most used traditional leafy vegetables in the Vhembe district. The results of this study will help people determine the water needs of each crop, which in turn will assist in saving water.

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APPENDICES

APPENDIX 1: CAPACITY BUILDING

Capacity building in this study refers to the assistance provided to students, community members, and other stakeholders.

Human capacity development (Student)

An MSc student (Ms Faith Maganyane) was participating in the project, and the title of the dissertation in fulfilment of the MSc degree was "Effect of macadamia husk compost on growth, yield, and nutritional quality of jute mallow (*Corchorus olitorius)* grown under different water regimes." The student conducted an experiment to fulfil objective 4 (to determine indigenous vegetables that are drought-tolerant and require less water, with reference to Jute mallow) of the project. The study was approved by the University of Venda's faculty research ethics committee, and an ethics approval certificate with ethical clearance number FSEA/24/PSS/15 was provided. Ms Maganyane has submitted her MSc thesis for examination and will be graduating in the next coming graduation ceremony.

Community and institutional development

A workshop was organised to inform smallholders about the importance of producing, consuming, and selling traditional leafy vegetables. Farmers were encouraged to plant traditional leafy vegetables to supply them to local and national markets. A training was held in alliance with the National Department of Agriculture (DoA) where smallholder farmers and students from Madzivhandila College of Agriculture were trained on how to plant, manage and harvest traditional leafy vegetables. Farmers were also trained to harvest and store seeds of traditional leafy vegetables for future use.

APPENDIX 2: Survey questionnaire

Title: Conservation of local knowledge on traditional leafy vegetables in Vhembe District

Instructions: Please answer all questions to the best of your knowledge.
Section A is compulsory
Select sections which suit you best amongst Section B, C and D
Fill in appropriate box by making a cross [x]

Questionnaire Number

Date of Interview

A. <u>Demographic information</u>

A1. Please indicate your Municipality

Thulamela	
Makhado	
Musina	
Collins Chabane	

A2. Residential area

A3. Please indicate your gender

Male	
Female	

A4. Which age group do you belong to?

16-35	
36-55	
56-65	
> 65	

A5. Which of these describe you?

Married	
Divorced	
Widowed	
Single	

A6. What is the highest level of education you have achieved?

None	
Basic education	
College/TVET Diploma	
Undergraduate Degree	
Honours Degree	
Master’s degree	
Doctorate	

A7. What is the main source of your income?

Grant	
Wage/salary	
Farming	
Other	

A8. How many members of your households are working?

A9. What are the monthly food expenses for your household?

< R500	
R500 – R1000	
R1000 – R2000	
> R2000	

A10. How big is your home garden or farm?

< 1 ha	
2-3 ha	
4-5 ha	
> 5 ha	

A11. What part do you play in the local vegetable industry?

Producer	
Consumer	
Seller	
Producer & Seller	
Producer & Consumer	
Consumer & Seller	
Producer, consumer & seller	

A12. What do you believe to be the main reason behind the low standard of living in your neighborhood?

Unemployment	
Corruption	
Lack of education	
Lack of land	
All above	
Other	

B. <u>Consumption information</u>

B1. Why do you eat traditional vegetables?

No other options	
Health benefits	
Nutritional value	
Health & Nutrition	
Other	

B2. How often do you eat/consume traditional vegetables?

Once a week	
2-3 times a week	
4-5 times a week	
6-7 times a week	
Sometimes	

B3. Where do you get traditional vegetables, you eat?

Own garden	
Wild	
Market	
All above	
Other	

B4. Which are the most commonly consumed traditional leafy vegetables in your area?

____

____

____

B5. Which traditional leafy vegetable is your favourite and why?

____

____

B6. In which form do you consume these vegetables?

Fresh	
Dried	
Both fresh & dried	
Other (specify)	

B7. Do you preserve traditional leafy vegetables?

Y	N

B8. If the answer is yes, how and why do you preserve them?

____

____

____

____

B9. What are the nutritional benefits of consuming traditional vegetables?

____

____

____

B10. Provide a list of the most common traditional vegetables in your area alongside with their medicinal value.

B11. From your experience, what do you think are the challenges contributing to limited consumption of traditional vegetables in your area?

B12. How can government assist to address these challenges?

C. Production information

C1. What is the size of your farm/home garden?

< 1 ha	
2-3 ha	
4-5 ha	
> 5 ha	

C2. Please indicate your farming experience (in years)

C3. Which traditional vegetables do you cultivate and why?

C4. When do you plant each of the traditional vegetables that you have mentioned above?

C5. Where do you get seeds and or other planting materials for traditional vegetables?

Other famers	
Wild	
Home garden	
Seed banks	
All above	
Other	

C6. What is the biggest obstacle to growing traditional vegetables?

Lack of land	
Lack of finance	
Lack of seeds	
Lack of market	
All above	
Other (Specify)	

C7. Which traditional leafy veggies, in your opinion, require less water and can withstand drought?

____

____

____

C8. Do you irrigate/ water your traditional leafy vegetables?

Y	N

C9. If yes, where do you get the water for irrigation?

River	
Municipal water	
Borehole	
Spring	
Dam	
Canal	
Other	

C10. What type of irrigation system do you have?

Bucket system	
Flood irrigation	
Furrow irrigation	
Sprinkler irrigation	
Drip irrigation	
Other	

C11. How often do you irrigate?

____

C12. If you don't have access to irrigation water, which traditional vegetables would you go for? ____

____

C13. Which fertiliser do you apply?

None	
Chemical fertilisers	
Organic fertilisers	
Both	

C14. How much of traditional vegetables do you harvest per season?

1 Kg	
2-3 Kg	
4-5 Kg	
> 5 Kg	

C15. What do you do if you produce more than what you can sell?

Share with the neighbours	
Dry them	
Throw them away	
Other (Specify)	

C16. What type of support do you get from the government?

____

____

____

C17. If the answer above is none, which support do you need from government or any other organisations in order to sustain this business?

____

____

D. <u>Selling/Marketing information</u>

D1. Where can I find traditionally grown veggies that I can sell?

Producers	
Wild	
Own garden	
All above	
Other	

D2. Why do you sell your traditional vegetables?

____

____

____

D3. Which traditional leafy vegetables do you sell?

____

D4. Where do you sell your traditional leafy vegetables?

Market place	
Along the road	
House to house	
Other	

D5. How much is a bunch of traditional leafy vegetable?

____

____

____

D6. Which traditional vegetable/s do you think has the highest capacity to generate income?

____

____

D7. Do you think rural people can alleviate poverty through producing and selling traditional vegetables? If the answer is yes, How?

____

____

D8. Do you have selling contract/s with retailer shops?

Y	N

D9. If yes, which retailer/s?

____

D10. Who are your biggest clients?

Local people	
Retailer shops	
Tourists	
Caterers	
All above	
Other (Specify)	

D11. What challenges do you encounter when selling traditional vegetables? ____________________

____
____
____

D12. Do you have many competitors on the market selling the same product as you?

Y	N

D13. If the answer above is yes, what do you do to be the best among your competitors? ____________

____
____
____

Thanks for your participation and honesty