AN INVESTIGATION OF MAFIKENG RURAL VILLAGERS' KNOWLEDGE AND USE OF AFRICAN INDIGENOUS LEAFY VEGETABLES (AILVS), AND THE ROLE OF EDAPHIC FACTORS AND HUSBANDRY PRACTICES IN THEIR POSSIBLE DOMESTICATION.

BY

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DEDICATION

This work is dedicated to my Mum and late Dad as well as my dedicated supervisor as his first student in Republic of South Africa.

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ABSTRACT

The role of wild African indigenous leafy vegetables (AILVs) for nutritional and medicinal purposes, and in food security is recognized in African countries; however, their use and consumption in South Africa is diminished since they can be associated with poverty and low self-esteem among rural people.

Part one of the study was conducted to investigate villagers' general knowledge and utilization of AILVs through a survey conducted among thirty randomly selected households in each of the three villages (Lokaleng, Moshawane and Tsetse) in the Mafikeng area of South Africa. Data was collected using a structured questionnaire administered face to face (personal interview) with the researcher completing the questionnaire as each villager responded. The results showed that all villagers have knowledge of the most common AILVs. The most common AILVs recognized and used were *Amaranthus species, Vigna unguiculata, Cucurbita maxima, Cleome gynandra* and *Chenopodium album.* However, *Amaranth, C. gynandra* and *C. album* were identified as the three most commonly used AILVs as sources of food. Most participants (67%) cited that in the presence of both AILVs and exotic vegetables, they would preferred AILVs for food. This preference of AILVs versus exotic vegetables was age specific but not gender specific. The youngest age group <20 was the only group which preferred exotic vegetables (63%). Additionally, it was determined that AILVs were simply used as found in the wild and were not domesticated.

Part two of the study was conducted out to determine baseline soil parameters influencing the AILV growth with the hope that such knowledge would aid in the domestication of AILVs by villagers. Soil samples (topsoil and subsoil) from the three villages were collected from sites where the three most preferred AILVs (as determined by the survey in part one) were found growing. Samples were analyzed for soil physical (texture) and chemical properties (pH, %OC, %OM, available P, total soil N, and extractable K).This study established that *Amaranthus spp, C. gynandra and C. album* grow well in soils with high organic matter. The results of soil analysis in AILV growth areas indicated higher levels of %OM and available phosphorus as compared to control soils. The observance of kraals and rubbish heaps near the areas of soil sampling confirmed the importance of organic matter in promoting AILV growth. Soil pH analysis indicated a wide range of soil pH for AILV growth with topsoil pH ranging around 6.5

to 7.4. Therefore, the study suggests that organic matter addition to soils may increase AILV growth and may be used as a fertilizer for domestication of AILVs, thus the motivation for part three of this study.

There is very little information on the optimal soil environments with regards to AILV growth. Alhough most AILVs are believed to grow in a wide range of soils, it is crucial that each crop be studied so that this latter statement may be based on fact. This motivates for research on each specific AILV in order to avoid generalizing knowledge across all AILVs. Knowledge on specific plants may even encourage farmers to domesticate such plants, which presently is not a common practice.

C. gynandra (Spider plant) is one of the most significant wild indigenous leafy vegetables in Africa. Knowledge of husbandry practices influencing the growth of *C. gynandra* is scantier. Part three of this study determined the effects of cattle manure and defoliation frequency on the growth and yield of *C. gynandra*. The experimental design was a randomized complete block design with four replicates. A factorial arrangement of 4 x 3 combinations was used. Treatment combinations consisted of four manure levels (0 ton ha^{-1}, 15 tons ha^{-1}, 30 tons ha^{-1} and 45 tons ha^{-1}) and three defoliation frequencies, (weekly, bi-weekly and 9 weeks after transplanting (WAT)). The results indicated that cattle manure application had a significant effect on growth and yield parameters (dry weight, leaf number, plant height). The highest yield (1.73 g/pot) was obtained with a 45 tons ha^{-1}rate which was not significantly different from the 30 tons ha^{-1} rate (1.51 g/pot). The highest leaf number was obtained with a rate of 45 tons ha^{-1}, which was not significantly different from 30 tons ha^{-1}.The greatest plant height (55.1cm) was recorded for 45 tons ha^{-1}. There was no significant difference in average plant height for 0, 15 and 30 tons ha^{-1} (43cm, 49cm and 51.2cm respectively). Harvesting frequency had a significant effect only on dry weight (yield). There was no significant difference on yield recorded for either weekly or bi-weekly harvest. In conclusion the study recommends that farmers use 30 tons/ha-^{1} cattle manure and harvest bi-weekly. The results also established that soil properties (soil pH, organic carbon, organic matter, and available phosphorus) increased with an increase in manure application and not with harvesting frequency. Therefore, the study concluded that cattle manure is an available fertilizer resource for farmers for increasing AILV growth and yield.

DECLARATION

I, Keeme Mooketsi declare that this dissertation for the degree of Master of Science in Agriculture (Crop Science), submitted at the NorthWest University, has not been previously submitted by me for any degree at this or other university and that it is my own work in design and execution. All the material contained herein, has been appropriately acknowledged.

Signed by: Keeme Mooketsi

Signature: ...KMooketsi.....

Date ....

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CHAPTER 1

INTRODUCTION

There is a wide variety of wild indigenous leafy vegetables found in Africa hence they are called African leafy vegetables (ALVs). Abukutsa-Onyango (2007) defines ALVs as African indigenous or traditional vegetables, whose leaves, young shoots and flowers are consumed. These vegetables are referred to as "indigenous" since they are native or originate in Africa. However, some leafy vegetables have been introduced to Africa and have evolved through natural selection or farmer selection and have become an integral part of African food culture (Laker, 2007). Such plant species are referred to as indigenized plant species. Almedom & Muller (2008) highlighted that traditional vegetables may be wild or managed. For this study the combination of both indigenous and indigenized leafy vegetables and wild leafy vegetables are synonymously referred to as African indigenous leafy vegetables (AILVs).

AILVs are sources of many nutrients, vitamins, antioxidants, minerals, and important proteins (Akula *et al.,* 2007). Some AILVs are mainly used by locals for medicinal purposes (Eifediyi *et al.,* 2008). Indigenous vegetables may be sold locally, thus improving the economic status of local communities. These wild vegetables vary according to location, as a result of differing climatic conditions. For instance, *Amaranth* species differ significantly due to location and morphology. This in turn leads to inhabitants of a certain community recognizing the species in their community alone and assuming that the species in another location is a weed. This statement is supported by Luchen & Mingochi (1995), who stated that most wild or traditional plants are specific to areas and ethnic groups. This indicates that a certain ethnic group may acknowledge and use only a few and regard others as weeds, while another ethnic group may acknowledge such species as food.

Despite the usefulness of these AILVs, they remain under threat of being lost. This is a result of poor harvesting methods such as uprooting or harvesting which involves destroying the entire plant and harvesting the reproductive parts before or at seed formation (Luchen & Mingochi, 1995). Farming practices such as veld fires also promote the extinction of these plant species by destroying seeds. Other critical factors include land clearing for agriculture, urbanization, industrialization and population increase, which result in a demand of land for settlements. These actions destroy AILVs or take the space which these plant species could have occupied.

In most instances the knowledge of AILVs is with older people, therefore, AILV knowledge stands a chance of being lost due to aging or people changing lifestyles. For instance, when rural villagers knowledgeable on AILVs migrate to towns, the knowledge they have gradually diminishes as it is no longer practiced and imparted on the following generations. In a survey study, Hendriks *et al.* (2006) showed that AILVs knowledge correlated with age. The latter also determined that educational status improved AILVs knowledge for middle-aged participants but not for the youth. Shava (2005) discovered that knowledge of wild food plants is widely distributed amongst ordinary people in most rural communities. The latter further indicated that the elderly are considered repositories of indigenous knowledge.

The knowledge by elderly people mostly concerns the identification, characterization and the utilization of AILVs, while soil aspects influencing AILVs are unknown. Soil supports and sustains plants by providing anchorage, providing essential nutrients and water to plants. The latter is supported by Sharma (2005) who emphasized that all plants need soil as a place to grow as it provides physical support as well as nutrients to plants. In most instances, AILVs are not grown as garden crops but simply harvested from the wild or around homesteads. Soil analysis is very significant for this study, to give an idea on baseline soil requirements for growth of indigenous leafy vegetables.

Crop husbandry is an understanding of how plants grow and what they need and it is a useful guide for providing crop requirements (Lockhart & Wiseman, 1988). Knowledge of husbandry practices influencing AILVs growth is scanty (Hendriks *et al.*, 2006). Studying the influence of husbandry practices on the growth of AILVs will contribute to a better understanding of appropriate management practices of such plant species. Previous studies show that AILVs have the potential for domestication. This is because AILVs are described as being adapted to harsh environments and generally require simpler technologies and inputs to grow than exotic vegetables

(Groeneveld *et al.*, 2009). Therefore, knowledge of their husbandry is essential for improving their production.

One crop husbandry practice for improving crop growth is the use of manure. Cattle manure is cheap, easy to find and affordable to most low income people of rural villages. Cattle manure can be a valuable source of plant food, particularly nitrogen, phosphate and potassium as well as various micronutrients (Lockhart & Wiseman, 1988). Another husbandry practice is harvesting frequency. It is a very crucial aspect in the growth of any vegetable plant since it may increase or reduce vegetative growth. Materechera and Medupe (2006) observed that shorter cutting intervals of two weeks enhanced re-growth of amaranth, while frequent (weekly) cutting did not give the leaves sufficient time to re-grow and consequently resulted in lower foliar yields. Therefore, it is important to determine harvesting frequency for each vegetable, as their response to cutting frequency may vary from one plant to another.

The main objective of this study was to increase awareness of the importance and utilization of AILVs and the important role they can play in food security and also to determine baseline edaphic factors and husbandry practices for AILV growth so as to increase their productiveness if they are domesticated. The specific objectives were:

- To determine the level of knowledge and utilization of AILVs among rural villagers in the Mafikeng area of South Africa.
- To determine the baseline edaphic factors (soil properties) under which the three most commonly used AILVs in the rural areas of Mafikeng grow in their natural habitat.
- To determine the effect of cattle manure and harvesting frequency on growth and yield of *C. gynandra* (one of three identified commonly used AILVs in the rural areas of Mafikeng). .

In this study it has been hypothesized that:

- People's knowledge of indigenous AILVs influences their use of those plant species.
- Edaphic factors influence the growth of AILVs.

- Various rates of cattle manure application and harvesting frequency influence AILV growth and yield.

CHAPTER 2

LITERATURE REVIEW

2.1 African Indigenous leafy vegetables (AILVs)

Plants can be classified as indigenous or exotic according to their place of origin. Within the context of Africa, indigenous plants are genuinely native to Africa, while indigenized species originated in other continents like Asia, South and Central America, but have become part and parcel of traditional African food culture and agriculture (Laker, 2007). There is a wide variety of African indigenous leafy vegetables (AILVs) among the indigenous plants which are used by various African ethnic groups for nutritional and medicinal purposes. Eifediyi *et al.* (2008) pointed out that the use of AILVs is part of African cultural heritage, and they play an important role in the tradition and food culture of African households.

2.2 Nutritional value of African indigenous leafy vegetables

AILVs play a very important role as a source of nutrients to the human body. Abukutsa-Onyango (2007) emphasized that these vegetables contain more than 100% of the recommended daily allowances for vitamins and minerals and 40% of proteins required for growing children and lactating mothers. This depends upon the frequency of intake, portion size and preparation method. AILVs consumption ensures the intake of various essential vitamins and mineral elements thus avoiding the problem of malnutrition (Yamaguchi, 1983). Malnutrition predisposes the body to many infections, stunted growth, and even diseases such as anaemia, cancer, rickets, heart diseases, marasmus, stroke, chronic diseases, blindness and scurvy. Alleman (2006) pointed out that the problem of malnutrition is escalated among children and pregnant women, and is responsible for high mortality rates among these groups. Insufficient consumption of vegetables and fruits causes 2.7 million deaths worldwide annually, and is one of the top ten risk factors contributing to human mortality (Akula *et al.*, 2007). Ekunwe & Emokaro (2007) also supported the latter author stating that two billion people, about a third of the world's population, live on diets that do not contain sufficient amount of vitamins and minerals that are needed for growth, development and the prevention of other disabilities.

This necessitates the inclusion of indigenous leafy vegetables (especially where exotic vegetables are not affordable) in diets in order to alleviate problems of hunger and malnutrition which is most prevalent in several African countries. Maseko (2003) pointed out that the exclusion of vegetables from diets resulted in low vitamin A and C intake.

AILVs contain almost all the vitamins and mineral elements essential for boosting the immune system, physical and mental development, and metabolic processes (Afolayan & Flyman, 2006) while others possess laxative characteristics. The nutritional value of AILVs is higher than several known common vegetables (Kala *et al.*, 2008). This is also supported by Afolayan & Jimoh (2008), who reported that these vegetables were comparable with or higher in nutritional value than commonly used vegetables such as spinach, lettuce and cabbage. The diversity in traditional vegetables offers variety in family diets and helps to ensure household food security (Luchen and Mingochi, 1995). AILVs are mostly consumed as a soft green relish together with starchy food grains (Laker, 2007), thus they (AILVs) have become important parts of diets for such communities. In addition to direct nutritional contributions, vegetables also add colour, flavour and texture to meals and improve the digestibility of nutrients in the body (Maseko, 2003).

A list of some indigenous and exotic leafy vegetables is given in Table 2.1, showing that the nutritional composition of AILVs is comparable or higher than that of exotic vegetables.

2.3 Medicinal value of African indigenous leafy vegetables

AILVs can be used to combat some diseases caused by unbalanced diets as evidenced by the cases described below. Scarcity of vegetables in diets is a major cause of vitamin A deficiency, which causes blindness and even death in young children as well as increased rates of chronic diseases (Afolayan & Flyman, 2006). Green leafy vegetables are good sources of vitamin A which is required to prevent blindness, especially in children (Rubaihayo, 1994). Some wild vegetables are capable of preventing age related degenerative diseases like arteriosclerosis and stroke (Kala, *et al.*, 2008). Vegetables with high protein content (*Corchorus olitorious, Chenopodium*

Table 2.1 Nutritional composition of indigenous and exotic leafy vegetables per 100g fresh weight

Vegetables	Energy (K cal)	Moisture (g)	Protein (g)	Fat (g)	Fibre (g)	Ash (g)	Carbohydrate (g)
*Amaranth dubius***	49	85	4	0.2	2.87	3.42	7.86
Spinach*	26	91	3.2	0.3	4.3		
*Asystasia*** *gangetica*	50	85	3	0.5	1.63	2.84	8.27
Broccoli*	32	89	3.6	0.3	5.9		
Bidens ** *Pilosa*	39	88	5	0.6	2.92	2.82	3.72
Brussels sprouts*	45	85	4.9	0.4	8.3		
*Chenopodium album***	59	83	5	0.8	1.92	2.94	8.34
Cabbage*	24	92	1.3	0.2	5.4		
*Cleome monophylla***	39	88	5	0.7	2.14	3.01	3.40
Parsely *	44	85	3.6	0.6	8.5		
*Cucumis metuliferus***	43	87	4	0.7	2.42	2.73	5.55
Swiss chard*	25	91	2.4	0.3	4.6		
*Emex australis***	36	89	5	0.6	1.57	2.62	2.73
Chinese cabbage*	14	95	1.2	0.1	3.0		
*Galinsonga parviflora***	41	89	4	0.5	1.24	1.74	5.29
Cauliflower*	27	97	2.7	0.2	5.2		
*Justicia flava***	51	84	3	0.4	1.39	3.32	8.77
Celery**	17	94	0.9	0.1	3.9		
*Momordica balsamina***	53	85	5	0.5	2.75	2.07	6.82
Kale*	53	83	6.0	0.8	9.0		
*Portulaca oleracea***	23	93	3	0.3	1.21	1.86	2.65
Lettuce*	18	94	1.3	0.3	3.5		
*Solanum***	55	85	3	0.6	2.42	2.24	9.03

Sources: Akula *et al.*, (2007); Lorenz, (1980)
Key: * Refers to exotic vegetables ** Refers to AILVs

album, Amaranthus hybridus, Bidens pilosa and *Cleome monophylla*) are recommended for patients with protein deficiency diseases (Akula *et al.,* 2007; Eifediyi *et al.*, 2008).

Most AILVs are rich in ascorbic acid (Vit C), an antioxidant which helps to protect the body against cancer and other degenerative diseases like arthritis and type I diabetes mellitus (Eifediyi *et al.*, 2008). Afolayan & Flyman (2006) also reported that AILVs contain comparably high amounts of vitamin C, which is among other antioxidants responsible for promoting good health by preventing cancer and high blood pressure, stimulating the immune system and improving drug metabolism. AILVs rich in this vitamin include *Solanum nigrum* and *Amaranth spp* (Bester *et al.*, 2010).

Mineral calcium is required for strong bones, muscle contraction and relaxation, blood clotting, and synaptic transmission. *Amaranth* spp, *C. monophylla,* and *S. nigrum,* are high in this mineral and are recommended to correct mineral calcium deficiency (Akula *et al.,* 2007). *Amaranth spp, Talinum tringulare* and *Celosia argentea* have high potassium and magnesium contents, which are responsible for reducing blood pressure (Eifediyi *et al.*, 2008). Ayitey-Smith (1989) indicated that bitter leaved vegetables contain an alkaloid which is capable of reducing headaches associated with hypertension. Green leafy vegetables contain significant amounts of iron (Akula *et al.,* 2007) which are needed for haemoglobin formation, hence are recommended for patients suffering from anaemic convalescence (Eifediyi *et al.*, 2008). Vegetables belonging to *Mentha* spp are good for curing fever and heat apoplexy and are used as stimulants and diuretics (Akula *et al.,* 2007).

2.4 Economic value of African indigenous leafy vegetables

Wild vegetables are used as a source of income, especially in rural poor communities. The community harvests these vegetables and sells them locally. Wild vegetables remain the only alternative for those families that cannot afford expensive exotic vegetables. Akula *et al.* (2007) pointed out that AILVs represent an inexpensive but high quality nutrition source for the poor segment of the population. Ekunwe & Emokaro (2007) supported the latter statement by stating that animal protein has become prohibitively expensive compared to vegetables; therefore, the utilization of vegetables can be advantageous to those who cannot afford expensive animal food products (i.e meat). Many indigenous food plants grow wild, thus they can be collected freely and are available to everyone including the poor (Kabuye *et al.*, 1999). There is a good possibility of high returns from cultivating AILVs since most of these plants have shorter life spans than exotic leafy vegetables, hence can be cultivated three to four times a year.

2.5 Adaptation of indigenous leafy vegetables

Although indigenous vegetables are neglected in most crop production systems, they perform better under harsh climatic and resource-poor conditions as well as in areas with low production potential when compared to exotic vegetables (Lewis, 2004). Swai (1995) also stated that AILVs are adapted to local conditions, require minimum cultivation, lower inputs of water, chemical fertilizers and pesticides and can be grown in home gardens. Laker (2007) also indicated that indigenous or indigenized green leafy vegetables are often described as drought tolerant crops. AILVs are well suited for cultivation in large areas of southern Africa which have a low agricultural potential due to low or unreliable rainfall, poor soils and steepy topography (Lewis, 2004). These plants become very helpful in improving food security of the rural homesteads during time of food shortages, especially due to poor rainfall when arable agriculture has failed.

The life cycle of vegetables is closely linked to climatic and seasonal changes (Ekunwe & Emokaro, 2007). This implies that vegetables tend to flourish during certain seasons and climatic conditions. Dieme *et al.* (2007) stated that the growing period for AILVs varies greatly per species, locality and season with most AILVs becoming established in the spring, between October and December. Some farmers collect their seed when the plants reach maturity for drying and storage. They sometimes broadcast seeds around their homesteads when first rains come (Dieme *et al.*, 2007). Some make small gardens around their homesteads where they usually add either cattle or poultry manure. These vegetables become ready for consumption within a month of their establishment (Abukutsa-Onyango, 2007) when their flavour and palatability are highly favourable for human consumption. These plant species mostly grow and complete their life cycle in a very short period of time. Therefore, knowledge of their husbandry may be very useful since it can lead to the manipulation of either soil or ecological factors to increase AILV yields and possibly prolong the season of availability of the plants.

2.6 Status of AILVs utilization in Africa

AILVs are being utilized in various parts of Africa as part and parcel of food culture. However with modernization their use in many parts of Africa is declining. The utilization of AILVs in several countries is presented below.

Cameroon - Cameroon has a wide range of indigenous vegetables including many wild species only found in the lowlands or highlands (Berinyuy, Nguy & Boukong. 1997). Their true potential has never been exploited since standardized practices for their production have not been developed. They are always grown together with other crops that compete for the same nutrients. As well, the absence of a pricing structure as part of an overall agricultural policy discourages entrepreneurs who would like to produce these vegetables on a commercial basis.

Uganda - Uganda is endowed with agroclimatic conditions suitable for the cultivation of a wide range of African indigenous vegetables (Rubaihayo, 1994). However, few of these plants are domesticated with the majority being wild or volunteer plants. They are abundant in the rainy seasons but scarce during the dry season, except for a few grown mainly for selling in trading centres and urban markets (Rubaihayo, 1997). Efforts to collect and conserve traditional vegetables have been hampered by lack of funds. The commonly grown traditional vegetables include *interalia* Leafy *Amaranthus* species, *Basellaalba*, *Solanum aethiopicum*, *Solanum gilo*, *Solanum indicum sub spp distchum*, *Capsicum* species *Colocasia esculenta, Phaseolus vulgaris, Gynendropsis gynandra, Vigna unguiculata, Bidens pilosa, Manihot esculenta, Corchorus olitorius, Solanum nigrum, Abelmoschum esculenta, Cucurbita maxima*, and *Acalypha biparlita* (Rubaihayo, 2002). Rubaihayo (2002) further indicates that, although there is a wide variety of AILVs, their use have been underrated in favour of introduced exotic vegetables.

Nigeria - There is a wide variety of plant species used as AILVs (Lucas, 1988). AILVs are eaten with starchy staple foods and are essential sources of proteins, vitamins, minerals and amino acids (Okafor, 1997). These AILVs include *Amaranthus*, *Celosia*, Indian spinach, *Vernonia calvoana* (bitter leaf), *Telfairia occidentalis* (fluted pumpkin), *Cucurbita pepo*, roselle, *Talinum triangulare*, Solanum spp., and *Corchorus olitorius* (jute) (Lucas, 1988). The majority of these vegetables are still being harvested from the wild (Okafor, 1997). AILVs play a very important role in the economic status of some Nigerians who sell them for income. Njoku (1983) established that wild vegetables are available in daily markets especially in the dry season when the cultivated species are not available.

Kenya – The utilization of AILVs is very important for both rural and urban locations (Aagaard-Hansen *et al.*, 2005). There is fear that AILVs are toxic despite the advantages gained from these plants, thus this belief limits AILV utilization. The same findings were also established by Opole (1993) who stated that scientists believed that indigenous vegetables cannot be cultivated and that they are poisonous and nutritionally inferior to exotic cultivars. Some AILVs found *are Amaranthus hybridus* L. (or African spinach), *Asystasia mysorensis* T. Anderson, *Coccinia grandis* (L) Voigt, *Crotalaria ochroleuca* (Kotschy) Polhill, (Sunnhemp) *Cucurbita maxima* Duchesne ex Lam, (Pumpkin) *Portulaca quadrifida* (L). (Purselane), *Sesamum calycimum* Welw. var. angustifolium (Oliv.) Ihlenf. (Onyulo), Siedenst. *Senna occidentalis (*L), and *Sida acuta Burm* (Sida) (Opole, 1993). Maundu (1997) established that the domestication of AILVs is very minimal. The latter mentioned that out of approximately 200 indigenous plant species used as leafy vegetables in Kenya, only a few (4) have been fully domesticated. Fifteen are semi-domesticated while the majority are wild.

Ethiopia - Ethiopia exhibits a different trend in regards to AILVs domestication. Approximately 27% of the crop species cultivated in home gardens in Ethiopia are vegetables, many of them AILVs (Asfaw, 1995). As well, approximately 29% of the plant species utilized from their natural habitat are vegetables, most of these being indigenous. The rural people of Ethiopia are endowed with knowledge concerning the use of wild plants, some of which are consumed during times of drought, war and other hardships (Abebe & Ayehu, 1993). Wild-food consumption is still very common in rural areas

(Guinand & Lemessa 2001). Ethiopia is thus referred to as a "biodiversity hot-spot'e" and known as a centre of origin for a significant number of food plants (Guinand & Lemessa, 2001).

Republic of South Africa – There is a wide range of AILVs present in South Africa; however, the utilization of AILVs is hampered by many constraints. Faber *et al.* (2007) outlined the factors that affect South African usage of AILVs. These factors are 1) poverty status, degree of urbanization and distance to fresh produce markets, 3) time of year and 4) social disturbances. Faber *et al.* (2007) indicated that poor households tend to use these types of leafy vegetables more than their wealthier counterparts because they lack the financial means to purchase vegetables and the inputs to produce their own vegetables. AILV usage may increase if the income earner becomes unemployed or during periods of drought since they are able to survive these conditions better than exotic vegetables. As people flee their homes to escape political violence they collect and utilise AILVs for survival. It is clear from above given factors that AILVs are mainly used in South Africa by people hard pressed by the above factors. Stevens *et al.* (2008a) further indicated that the informal cultivation and harvesting practices of traditional leafy vegetables (TLVs) led to their denigration/belittling by both agricultural research and extension since the 1960s.

According to Ineke *et al.* (2007) there are many AILVs found in South Africa most of which belong to *Amaranthaceae, Chenopodiceae, Capparaceae, Fabaceae* and *Cucurbitaceae*. Generally, amaranth, *C. album* and *C. gynandra are the most commonly known and used in South Africa* from the above families.

Amaranthus spp include *Amaranthus hybridus* (L), *A. Thunbergii, A. greazicans,L, A. spinosus, A. Viridus, A. hypochondriacus* and *A. deflexus* (L) (Faber *et al.*, 2007). *Amaranth* spp have an extremely broad climatic adaptability which permits them to adapt with minimum management (van den Heever, 1995). Faber *et al.* (2007) also emphasized that amaranth is rarely cultivated in South Africa as with other AILVs because people believe the plants grow naturally. According to Ineke (2007), C. gynandra is a wild weed plant that is mainly collected by women in the fields in the

Northern parts of South Africa. Faber *et al.* (2007) indicated that *C. gynandra* is the most widely used AILV among the different *Cleome* spp.

2.7 Husbandry practices

In any crop production system, husbandry practices are utilised with the aim of providing crop plants with all their essential growth requirements. Husbandry practices may include soil parameters such as fertilization, and crop parameters such as harvesting frequency, in order to increase crop growth and yield.

2.7.1 Fertilization with cattle manure

Soils may not contain sufficient levels of essential nutrients to produce quality crops. These nutrients can be supplied to the plant through organic fertiliser (manures and compost) amendment to the soil which also improves soil physical properties (Ceronio *et al.*, 2008). Cattle manure usually referred to as farm yard manure (FYM) is one of the organic nutrient sources used in various cropping systems. Abukutsa-Onyango (2007) emphasized that organic nutrient sources, besides providing nutrients to the crop plants, also improve the structure of the soil and give residual effects on subsequent crops. Farm yard manures consist of a mixture of dung, urine and litter used for bedding (Russell, 2006). Farm yard manures are valuable sources of plant food, particularly nitrogen, phosphate, potassium as well as various micronutrients (Lockhart & Wiseman, 1988). This is also supported by Ceronio *et al.* (2008) who indicated that using manure provided necessary plant nutrients and increased the population of soil micro-organisms which helped to facilitate organic matter mineralization. An important consideration when applying manure is to ensure that adequate time is allowed for mineralization to occur, thereby increasing nutrient availability to plants (Lockhart & Wiseman, 1988).

Cattle manure use for AILV cultivation has shown some growth and yield improvements. According to Akundabweni *et al.* (2003), the vegetative growth and leaf yields of *Solanum villosum* were considerably improved when farmyard manure was applied in comparison to the application of inorganic N fertilizer. Similar results were also reported by Akundabweni *et al*. (2006), who found that the *Cleome. gynandra* yields obtained when grown with cattle manure were generally higher than those grown with inorganic N (calcium ammonium nitrate). Mkabela *et al.* (2008) reported that manure application substantially increased crop yield in a field investigation that was conducted to assess the impact of manure in agricultural systems using amaranth, beans, cassava and maize. Kimbi *et al.* (2001) also reported that the yield of amaranth increased over successive harvests during the three months of a field experiment. They observed an increase in soil available N and P with increasing application rates of the animal manure which they attributed to increased microbial activity.

2.7.2 Harvesting frequency

Harvesting frequency is an important factor, especially in the productivity and yield of leafy crops (Materechera & Medupe, 2006). Their study of amaranth as an indigenous leafy vegetable showed that it is very crucial to know how often and at what stage leaves should be cut. This is because pruning encourages new leaf production. Chiveu & Opile (2005) observed that pruning as a method of harvesting led to higher productivity of amaranth. They attributed higher productivity with the reduced apical dominance following cutting. This promoted the production of lateral branches resulting in the production of higher harvestable shoots. Agbo *et al.* (2006) also established that most farmers utilize multiple harvests for leafy vegetables. The quality of leaf is of great importance in leafy vegetables (Materechera & Medupe, 2006); therefore, harvesting at the end of plant life may yield coarse leaves. This implies that frequent harvesting may improve leaf quality as it allows new growth and palatable leaves.

CHAPTER 3

GENERAL KNOWLEDGE AND UTILISATION OF AFRICAN INDIGENOUS LEAFY VEGETABLES OF LOKALENG, MOSHAWANE AND TSETSE VILLAGERS

3.1 Introduction

There is a wide variety of African indigenous leafy vegetables that are mainly used for nutritional and medicinal purposes. The diversity in traditional vegetables offers variety in family diets and helps to ensure household food security (Luchen and Mingochi, 1995). However, there are some barriers that limit the utilisation of AILVs and hence may encourage their potential extinction.

First, Hendriks *et al.* (2006) emphasized that although the role of wild indigenous leafy vegetables in food security is recognized in other African countries, their use in South Africa has diminished and consumption is associated with poverty and low self-esteem among rural people. As people modernize they may turn away from old lifestyle practices. Today, young people mostly associate the use of AILVs with being inferior, old fashioned and poor (Stevens *et al.*, 2008b). This shows that AILVs are viewed negatively by young people. The latter statement is also supported by Kabuye *et al.* (1999) who argued that the 21st century generation has adopted western culture which introduced new food habits and new crops, hence they neglect African foods. Thus, it is very challenging to educate and encourage people to change their negative attitudes towards AILVs and thereby increase their utilization.

Second, Dovie *et al.* (2007) highlighted that although edible herbs (some of which are AILVs) have high levels of important nutrients, some may have toxic effects if intake exceeds certain limits. Thus, due to lack of knowledge, some people do not believe it is safe to use AILVs at all since they do not know where to draw the line.

These barriers that limit utilisation and increase potential extinction of AILVs may be overcome. Abukutsa-Onyango (2007) emphasized that promoting the production and utilization of AILVs will ensure conservation by utilization, and that as long as there is consumer demand for AILVs then production will be sustained to meet the demand and therefore avoid the threat of their extinction. For this study it has been hypothesized that peoples' knowledge of indigenous leafy vegetables influences utilization of such plant species. The objective of this study was to determine the level of knowledge and utilization of AILVs among rural villagers in the Mafikeng area of South Africa.

3.2 Materials and Methods

3.2.1 Description of study area

The study was conducted in Mafikeng, which lies at approximately 25°48′ S 25°38′ E in the Northwest Province of South Africa. Mafikeng is surrounded by many local rural villages. It was impractical and unaffordable (due to limitation of funds) to survey all such villages; therefore, a convenient sampling method was used to select three villages. These are Lokaleng, Moshawane and Tsetse (Fig. 3.1). A survey was conducted among thirty randomly selected households per village, allowing only one person per household to participate in an interview (refer to Appendix 1 for the survey). The last part of the questionnaire required participants to mention other people they know in their village that domesticate indigenous leafy vegetable species. If they answered "yes", then such people within the village were to be contacted in order to increase the data pool for determining the three most important AILVs per village.

Data were collected using a structured questionnaire administered face to face (personal interview) by May 2009. Personal interviews yield good responses since the interviewer can persuade respondents to participate. This is emphasized by Menden III *et al.* (2006) who emphasized that people will usually respond well when confronted in person. Thompson (1992) indicated that personal interviews are reliable as compared to other methods such as telephone or mail surveys. The latter highlighted that some people in the selected sample may be away when phoned or mailed. Such problems introduce non-responses with the result that the whole population may not be well represented in the survey. Problems such as misplacing questionnaires and the respondents taking too long to complete the questionnaire can be avoided. In personal interviews, the interviewer can note specific reactions and eliminate misunderstandings by further simplifying or clarifying asked questions (Menden III *et al.,* 2006). Therefore, problems such as the wrong interpretation of questions can be avoided. Closed questions were used to collect information from the respondents. The researcher completed the questionnaire form as the respondents answered. The language better known to respondents (this was Setswana in all cases) was used.

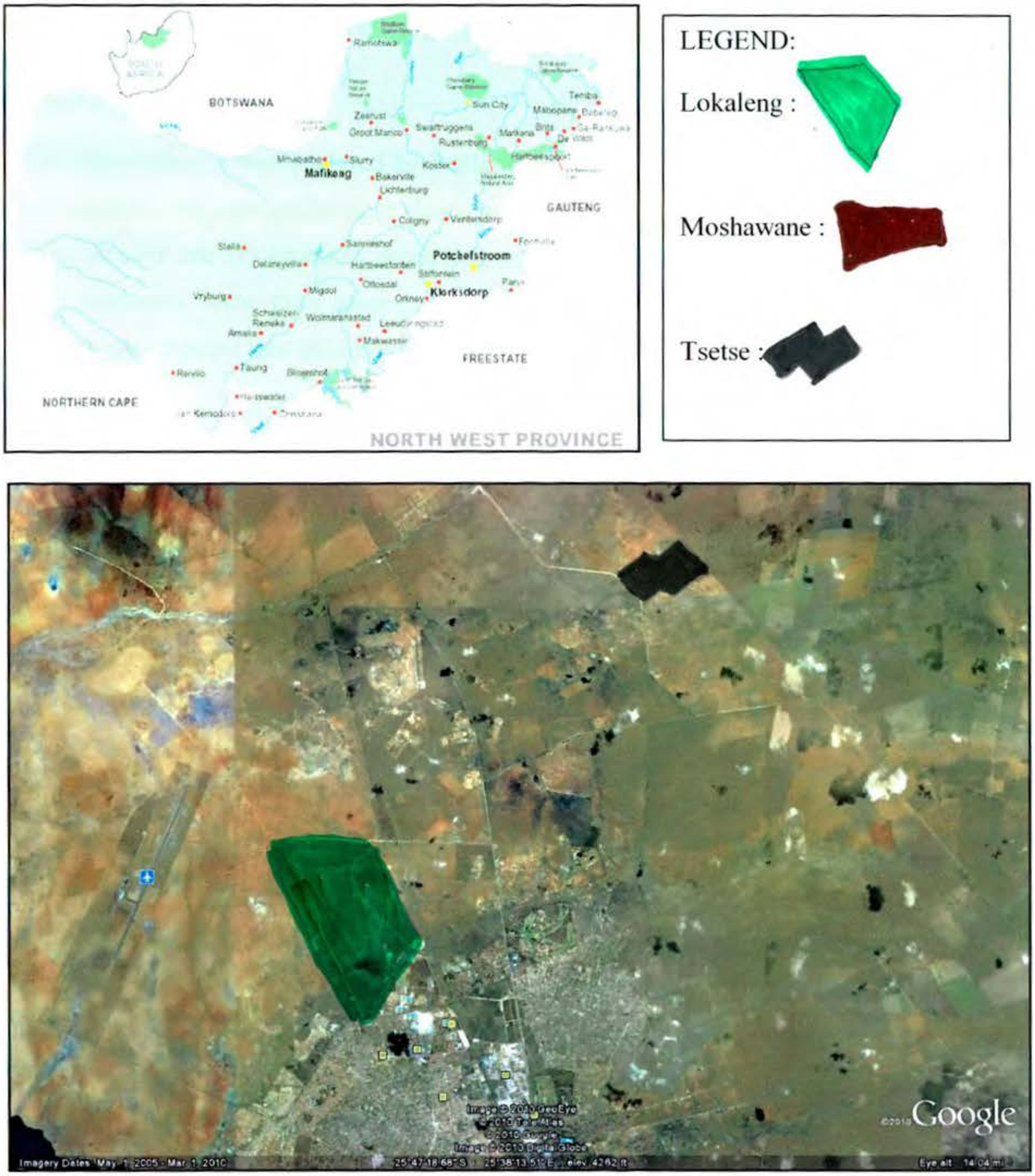

Fig. 3.1 – Location of Lokaleng, Moshawane, and Tsetse (rural villages in Mafikeng, in the Northwest Province of South Africa).

It was assumed that respondents were not familiar with soil texture descriptions such as sand, clay, and loam. Therefore, the interviewer explained these terms. Sandy soils were explained as soils that felt gritty and allow water to drain easily. Clay soils were explained as soils which feel sticky when wet and do not allow water to easily drain, and may show cracks when dry. Loam soils were explained as an intermediary between sand and clay soils.

The data collected was analyzed by Statistical Analysis System (SAS). Data coding and analysis was appropriate since closed questions were used. Responses were coded from number one (1) upwards, depending on the number of responses per question. The responses were then grouped into percentages, i.e. for each question; the percentage response was calculated by dividing Σn /code by ΣN population multiplied by 100.

3.3 Results

3.3.1 Demographic information

Respondents' demographic information is presented in (Table 3.1). Most participants were from the 21-40 year age group (43%), followed by the >60 year age group (24%), 41-60 year age group (23%), and the least being the <20 year age group (9%).The largest number of respondents (76%) were females. The majority of participants were single (69%) with a smaller percentage being either married or widowed persons (31%). The majority of respondents (62%) have non-formal education while only 38% have secondary school education. In this survey, non-formal education refers to all participants who either completed primary education or never attended school, while the secondary education refers to all respondents who have completed secondary or tertiary education. The unemployment rate was very high (89%) among participants. The majority of participants (92%) have resided in the study areas for more than 10 years.

Table 3.1 Demographic information of survey respondents.

Demographic category	**Response (# of people)**			**Response (%)**
	Lokaleng	**Moshawane**	**Tsetse**	
Age				
<20 yrs.	1	5	3	9
21-40 yrs.	14	13	16	43
41-60 yrs.	10	7	7	23
>60 yrs.	8	9	8	24
Gender				
Female	22	25	29	76
Males	11	9	4	24
Marital status				
Single	22	27	20	69
Married	11	7	13	31
Education				
Primary	24	26	12	62
Secondary	9	8	21	38
Occupation				
Unemployed	32	30	27	89
Employed	1	3	7	11
Residence period				
<5 yrs.	2	3	3	8
6-10 yrs.	0	0	0	0
>10 yrs.	31	30	31	92

3.3.2 Knowledge of AILVs

Participants from all villages cited that they have knowledge pertaining to AILVs (Table 3.2). In the communities, respondents recognised 11 out of 16 AILVs presented in the survey. Respondents also had knowledge of an additional 12 AILVs. The responses of participants' recognition of AILVs pictorially is given in (Table 3.3). The results show that Amaranth was the most recognized AILV (59%), followed by *C. gynandra* (46%), *V. uinguiculata* (27%) and *C. maxima.* (32%). Although the participants had knowledge of many plants, they had difficulty in recognizing them in pictures. Some participants complained that the pictures were not clearly visible. This complaint was with the age group of > 60 years and was most likely due to their poor vision. The AILV photos used in this survey are given in Appendix 1b.

Table 3.2 Respondents (villagers) knowledge of AILVs verbally (based on 30 respondents surveyed in each village)

AILVS	Response (# of people)			Total	
	Lokaleng	Moshawane	Tsetse	#	%
AILVs included in the survey					
1.Amaranth spp	30	30	30	90	100
2.Cochorus olitorious	4	15	7	26	29
3.Cleome. gynandra	19	20	25	64	71
4.Cleome monophylla	0	0	0	0	0
5. Vigna unguiculata	23	24	26	73	81
6 *Cucurbita maxima*	21	25	27	73	81
7. *Citrullus lanatus*	1	10	1	12	13
8.Bidens pilosa	0	0	2	2	2
9.Chenopodium carinatum	0	0	0	0	0
10. Chenopodium album	13	17	16	46	51
11. *Chenopodium murale*	0	0	0	0	0
12.Hypochaeris radicata	0	0	0	0	0
13.Portulaca oleracea	6	1	1	8	9
14. Urtica urens	0	0	0	0	0
15.Emex australis	4	3	0	7	8
16.Lactuca serriola	1	1	0	2	2
Others AILVs cited by respondents					
17 Seropolane	1	7	0	8	9
18 Thoma	6	2	1	9	10
19 Phate ya ngaka	1	0	0	1	1
20 Motetenyane	8	5	0	13	14
21 Monoto wa koko	6	3	0	9	10
22. Monyaku	12	8	6	26	29
23. Leshe	7	16	3	26	29
24. Shepashepe	2	11	0	13	15
25.Seruane	0	5	1	6	7
26. Moonyane	1	2	0	3	4
27.Ramogola	0	2	0	2	2

Pictorial recognition of AILVs was lower for respondents at Tsetse village as compared to the other two villages (Table 3.3). Tsetse villagers identified only 4 of the additional 11 AILVs which were recognized by respondents in Lokaleng and Moshawane. Two Tsetse respondents were familiar with *B. pilosa*, while the plant was unknown as a vegetable to both Lokaleng and Moshawane villagers. As well, Tsetse respondents had more difficulty identifying AILVs by pictures.

Table 3.3 Rural villagers' vegetable knowledge verified by pictures.

AILV	**Response (# of people)**			**Total**	
	Lokaleng	**Moshawane**	**Tsetse**	**#**	**%**
Amaranth spp	21	21	11	53	59
C. gynandra	12	13	16	41	46
C.maxima	10	17	2	29	32
V. unguiculata	10	14	0	24	27
C. olitorious	2	9	1	12	13
C. lanatus	0	7	0	7	8
P. oleracea	0	1	1	2	2
B. pilosa	0	0	1	1	1
E. australis	0	1	0	1	1

However, knowing about AILVs does not necessarily mean that participants utilise such vegetables since participants have their preferences. Table 3.4 presents participants AILV preference. Amaranth was cited as the most preferred vegetable (89%), followed by *C. album* (31.1%), *V. unguiculata* (30%) and *C. gynandra* (25.6%) Participants indicated that *Amaranth* spp grows more abundantly than other AILVs. Although results indicated *C. gynandra* as one of most preferred AILVs, it was established that the majority of respondents with a preference for this vegetable are from Tsetse followed by Lokaleng with only three respondents from Moshawane.

3.3.3 Utilization of AILVs by villagers

Responses to utilization of AILVs by villagers is presented in Table 3.5. A vast majority (94%) of villagers indicated that AILVs are used only for consumption purposes (Table 3.5). Although villagers use AILVs, only 6% indicated that they cultivate them, with 80% of these being from Tsetse village. It was observed that villagers in Tsetse have home gardens and mainly cultivate *V. unguiculata* along with exotic vegetables.

Table 3.4 Rural villagers' AILV preference.

AILV	Response (# of people)									Total	
	Lokaleng			Moshawane			Tsetse				
	1	2	3	1	2	3	1	2	3	#	%
Amaranth	27	0	0	26	0	0	27	0	0	80	89
C.album	0	4	4	0	11	6	0	1	2	28	31
V.unguiculata	0	2	2	0	2	0	0	7	14	27	30
C.gynandra	0	5	2	0	0	1	0	13	2	23	26
Leshe	0	1	1	0	3	6	0	0	0	11	12
Cochorus	0	0	1	0	0	0	0	0	0	1	1
Monyaku	0	6	1	0	0	3	0	0	0	10	11
C.maxima	0	0	0	0	1	2	0	2	4	9	10
Thoma	0	2	1	0	0	0	0	0	0	3	3
Motetejane	0	1	2	0	0	0	0	0	0	3	3
Shepashepe	0	0	0	0	0	1	0	0	0	0	1
Monoto	0	0	2	0	0	0	0	0	0	2	2
Seruane	0	0	0	0	0	1	0	0	0	1	1
Seropolane	0	0	0	0	0	2	0	0	0	2	2
Phate	0	0	1	0	0	0	0	0	0	1	1

1 = first preference ; 2 = second preference ; 3 = third preference

Approximately 77% of participants indicated that they transfer AILV knowledge to their children through their usage of AILVs (Table 3.5). This transfer of knowledge through usage was higher in Lokaleng than in the other villages.

A vast majority (82%) in all villages indicated that utilisation of AILVs in their village is high (Table 3.5). Most participants (67%) in all villages indicated a preference of AILVs in the presence of both AILVs and exotic vegetables (Table 3.5). Most participants mentioned that although they prefer AILVs they still use exotic vegetables a lot because AILVs have a very short growth duration period and that low rainfall reduces their availability (personal communication).

Table 3.5 Survey responses for evaluating villagers' knowledge and utilization of AILVs.

Parameter	**Response (# of people)**			**Total for all villages**	
	Lokaleng	**Moshawane**	**Tsetse**	**#**	**%**
Villager's vegetable utilisation					
Food	30	28	29	87	97
Medicinal	0	2	1	3	3
Any	0	0	0	0	0
AILVs domestication					
Yes	1	0	4	5	6
No	29	30	26	85	94
Knowledge transformation from parents to children					
Yes	27	22	20	69	77
No	2	4	7	13	14
Don't know	1	4	3	8	9
Utilisation					
High	25	23	26	74	82
Poor	4	4	3	11	12
Don't know	1	3	1	5	6
Vegetable Preference					
Exotic	8	10	12	30	33
AILVs	22	20	18	60	67

As well, the results of this study established that vegetable preference is not gender dependent (Table 3.6) but age dependent (Table 3.7). The majority of participants < 20 year age group indicated a 63% preference of exotic vegetables over AILVs. Vegetable preference as influenced by age is indicated by Chi-Square $p=0.0139$, $df=3$ at α 0.05 and Fisher tests pr <=p 0.0103 at α 0.05 (Table 3.7).

Table 3.6 Rural villagers' vegetable preference based on gender.

Preference			Total for all villages	
	Female	**Male**	**#**	**%**
Exotic	22	8	30	33
AILVs	46	14	60	67
			90	100

(Chi-Square $p=0.73$, $df=1$ at α 0.05 and Fisher test pr <=p 0.46 at α 0.05)

Table 3.7 Rural villagers' vegetable preference based on age.

Preference	Response (# of people)				Total for all villages	
	<20 yrs.	**21- 40 yrs.**	**41- 60 yrs.**	**>60 yrs.**	**#**	**%**
Exotic	5	17	2	6	30	33
AILVs	3	22	19	16	60	67
					90	100

(Chi-Square $p=0.0139$, $df=3$ at α 0.05 and Fisher test pr <=p 0.79 at α 0.05)

3.3.4 Harvesting method

Information on the frequency of harvesting methods as cited by respondents is given in Table 3.8. Harvesting methods were grouped into three categories, namely: leaf picking (leaf blade without stalk), leaf+branches (where leaf blade is cut together with stalk or the whole branch) and uprooting. The majority of respondents (70%) reported leaf picking as a commonly used harvesting method. The villagers indicated that this method increases the production of new leaves (personal communication). Although these results were common throughout the three villages, villagers in Tsetse utilised leaf picking at a 90% level. The results indicated that a vast majority of the Tsetse respondents used only one method of harvesting (leaf picking), while participants from other villages combined this method with other methods. It was also established that the method of uprooting was used only at Moshawane, where it is practised by a few people.

Table 3. 8 Rural villagers' knowledge on harvesting methods.

Harvesting methods	Response (# of people)			Total for all villages	
	L	M	T	#	(%)
Leaf picking	18	18	27	63	70
Leaf + branches	12	9	3	24	27
Uprooting	0	3	0	3	3
				90	100

L = Lokaleng; M=Moshawane; T=Tsetse

3.3.5 Knowledge of soil parameters influencing AILV growth

Villagers' knowledge pertaining to soil conditions (soil colour and soil type) influencing AILV growth is given in Tables 3.9 and 3.10. The results show that villagers do not have knowledge of these 2 soil parameters associated with AILV growth. Respondents cited "any" or "don't know" when asked to give any observation or knowledge on soil colour (79%) and soil type (78%) where AILVs are found. Generally, a majority of Lokaleng respondents cited "don't know" while at Tsetse and Moshawane the respondents mainly "any". If respondents cited a colour selection, "red" was their choice over 'black."

Table 3.9 Rural villagers' knowledge of soil colour.

Soil colour	Response (# of people)			Total for all villages	
	Lokaleng	Moshawane	Tsetse	#	%
Red	5	7	3	15	17
Black	0	3	1	4	4
Any	8	15	19	42	47
Don't know	17	5	7	29	32
	30	30	30	90	100

Table 3.10 Rural villagers' knowledge of soil type.

Soil type	Response (# of people)			Total for all villages	
	Lokaleng	Moshawane	Tsetse	#	%
Sandy	2	0	0	2	2
Clay	4	7	3	14	16
Loamy	1	2	1	4	4
Any	5	15	19	39	43
Don't know	18	6	7	31	35
	30	30	30	90	100

3.4. Discussion

Villagers had knowledge on given AILVs and beyond, as respondents additionally added to the list given in the survey. The results of this study clearly show that AILVs are used as part of food culture by villagers. Villagers acknowledged passing their AILV knowledge of AILVs to the young generation as a contribution of imparting African food culture. Villagers listed AILVs they know using their local names which at times made it difficult to identify plants. Respondents identified amaranth, *V. unguiculata, C. maxima C. gynandra* and *C. album* as the most commonly known AILVs. It was realized that although there are common AILVs, there are some plant species that are known to specific persons. Plants cited to be known by respondents are in line with those listed by Faber *et al.* (2007) as the AILVs of South Africa.

The preference of AILVs was higher than of exotic vegetables. Villagers mentioned that they use AILVs mainly because of their low economic status (personal communication). Thus, their lower economic status forces them to utilize the plant species in their environment as an available source of food. Akula *et al.* (2007) pointed out that AILVs represent an inexpensive food source to the poorer segment of the population. Faber *et al.* (2007) confirmed this when stating that poor households tend to use AILVs because they lack finances to buy exotic vegetables and the inputs for vegetable production. It was also evident that the preference of AILVs is age dependent with the majority of the younger age group with a preference for exotic vegetables. The young people also felt that since exotic vegetables can be easily accessed from shops; thus there is no need to go to the bush for vegetable gathering (personal communication). Stevens *et al.* (2008b) observed that a barrier to AILV utilisation is that the youth have a negative view of AILVs. This may be attributed to the change in food culture which has now influenced people to leave their old and traditional food culture and adopt a modern food culture.

The use of AILVs in Tsetse was much lower than the use in Lokaleng and Moshawane. This may be attributed to the fact that Tsetse is growing into a town where settlement allocation is similar to that done in urban areas. Plots are joined together and not scattered as observed in other villages like Lokaleng. On the other hand Tsetse villagers have gardens, where they grow exotic vegetables. Generally, in all villages, it was observed that apart from the commonly preferred AILVs, preference for other known AILVs is low. Some respondents attributed this to a lack of knowledge on AILV toxicity and safety for consumption. Although *C. gynandra* was a preferred AILV in Lokaleng and Tsetse, only one respondent from Moshawane had a preference for it. The respondents claimed that they did not prefer it because it is too bitter and requires a long cooking time.

This study has shown that although villagers use some AILVs, they do not domesticate them. Many villagers still think that it is not necessary to grow AILVs as they grow naturally, thus it will be wasting energy and resources. Only a few of the respondents at Tsetse domesticated AILVs.

The study established that villagers use the leaf picking harvesting method as the best method to enhance re-growth of AILVs. They understand that this method increases new leaf development through re-growth and ultimately increases production and yield of AILVs. Villagers who use the leaf+branches method mainly use it to give more weight to the harvest, since cooking only leaves requires harvesting an abundant amount of leaves (personal communication). Villagers do not use the uprooting method to avoid lowering future AILV production and possible extinction of plant species because the plants are uprooted before they produce seed.

It is evident that the respondents do not have knowledge of soil aspects influencing growth of AILVs. A majority of them cited "any" or "Don't know" on each case, when asked to give any observation or knowledge on soil type and colour where AILVs are found. Respondents outlined that as long as it rains well, AILVs will grow regardless of soil colour or type (personal communication).

In conclusion, this study has shown that there is a wide range of plant species used as indigenous leafy vegetables around the Mafikeng area. The study has also shown that knowledge of various AILVs by villagers does not necessarily mean that villagers use them, but that villagers have variant preferences. Evidence from this study shows that although many AILVs are known only a few are used. *Amaranth, C.gynandra* and *C.album* are the three most commonly used AILVs as sources of food in all three villages. However, despite much knowledge and utilization of AILVs, domestication of AILVs is negligible.

CHAPTER 4

SOIL CONDITIONS UNDER WHICH THREE COMMONLY USED AILVs (*AMARANTHUS* SPP, *C. GYNANDRA* AND *C. ALBUM*) GROW IN THEIR NATURAL HABITATS IN LOKALENG, MOSHAWANE AND TSETSE VILLAGES

4.1 Introduction

Beaton *et al.* (1993) emphasized that the main purpose of soil is to keep plants erect, protect them from heat and cold and to provide plants with substances unique for their own particular nourishment from the soil. Therefore, soil plays a very significant role in supplying all essential nutrients needed for the completion of crops' life cycles. African indigenous leafy vegetables (AILVs) grow in a wide range of soil conditions. Groeneveld *et al.* (2009) emphasized that AILVs have adapted to harsh environments and generally require simpler technologies and inputs to grow than exotic vegetables. Abukutsa-Onyango (2007) indicated that AILVs have the ability to withstand drought and low soil fertility. If a farmer is to provide the best possible conditions for crop growth, then it is essential to have an understanding of the soil and management practices to maintain its fertility (Lockhart & Wiseman, 1980). However, Akundabweni *et al.* (2003) emphasized that agronomic data or information necessary for improving production and productivity are either lacking or too scanty to be useful.

The results from a survey study of three rural villages (Lokaleng, Moshawane, and Tsetse) in the Mafikeng area of South Africa (Chapter 3) indicated villagers' preference for 3 AILVs, which were *Amaranth* spp, *C. gynandra* and *C. Album*. There is very little information on the optimal soil environments with regards to the growth of these AILVs. Although most AILVs are believed to grow in a wide range of soils, it is crucial that each crop be studied to determine their particular requirements. Knowledge on specific AILVs may even encourage farmers to domesticate such plants, which presently is not a common practice in the study area. The latter statement is supported by Dovie *et al.* (2006) who stated that not much information exists on the cultivation and domestication of most of these plant species.

Soil analysis is very important to give an idea of the baseline soil parameters for the possible domestication of AILVs. Campbell (2003) indicated that this knowledge is essential for understanding the soil fertility status and to guide farmers in ways to improve their soil in order to provide a good environment for plant growth.

The objective of this part of the study was to determine baseline soil parameters in growth areas of *Amaranth*, *C. gynandra* and *C. album* with the hope that such knowledge will aid in the domestication of AILVs by villagers. This study has focused on these three AILVs, since they were cited as the most important AILVs per surveyed village.

4.2 Materials and Methods

Soil samples under which three commonly used AILVs (*Amaranthus* spp, *C.gynandra* and *C. Album*) grow in Lokaleng, Moshawane, and Tsetse villages were collected for characterization and analysis (see Figs. 4.1 – 4.3). Two soil samples (topsoil and subsoil) were collected from AILV growth areas <10 m^2. The sampling was doubled if the AILV growth area is between 10 m^2 and 20 m^2. The sampling was tripled if the growth area was between 20 $m^2$and and 30 m^2. There were no observed AILV growth areas >30 m^2. The topsoil sample (approximately 1 kg) was collected to a depth of 0-30 cm using a 5 cm diameter core sampler. Subsoil samples were collected for the 30-40 cm soil depth using the same soil core sampler. Two soil samples (topsoil and subsoil) in non-AILV growth areas were collected for each village for controls.

Soil samples were analyzed for physical and chemical properties. These include particle size distribution (Bouyocous method, 1951), soil pH (Miller, 1992), organic carbon and organic matter (Nelson & Sommers, 1982), available phosphorus (Bray #1 Method), (Dean & Olsen, 1965), total soil nitrogen (Anderson & Ingram, 1993) and extractable potassium (Barnard *et al.*, 1990). Refer to Appendix 2 for complete soil analysis procedures.

Fig. 4.1 - Soil sampling areas (indicated by green) in Moshawane village.

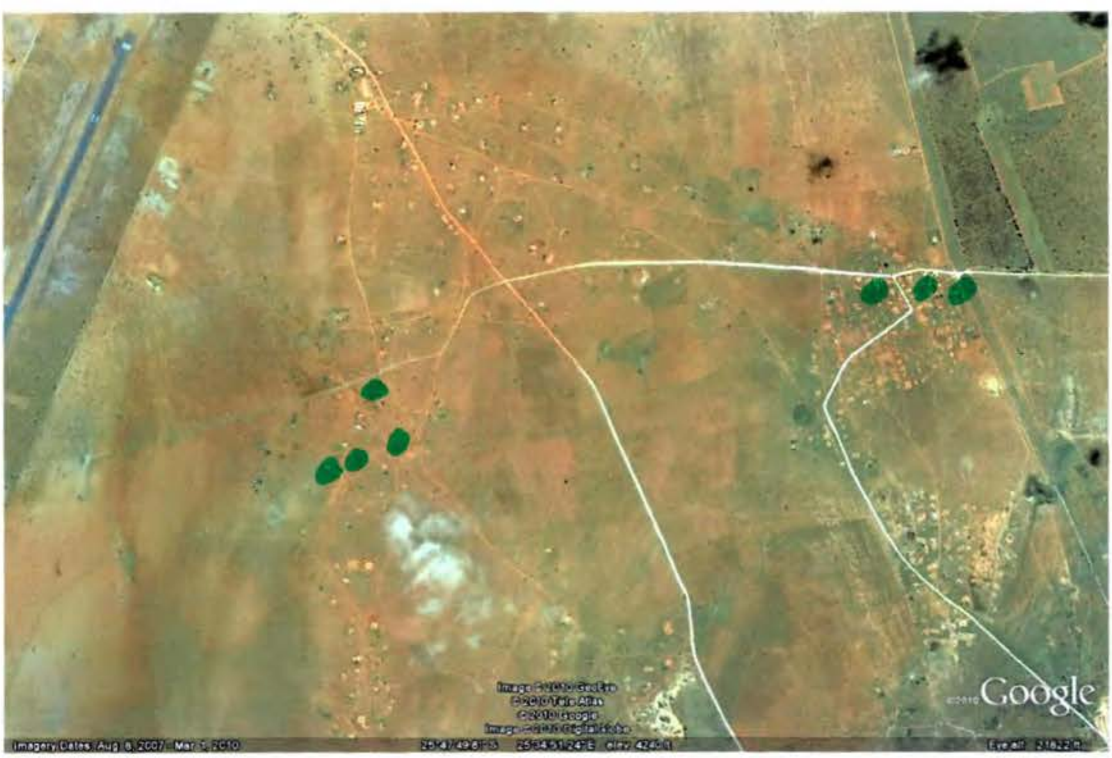

Fig. 4.2 - Soil sampling areas (indicated by green) in Lokaleng village.

Fig. 4.3 - Soil sampling areas (indicated by green) in Tsetse village.

4.3 Results

The results given as means, maximums and minimums of the measured soil parameters for AILV growth areas in the three villages are given in Table 4.1. Complete results for every sample are given in Appendices 4 - 9.

The results for particle size distribution per village are shown in Appendix 3. Only two textural classes (sandy loam and loamy sand) were found to be dominant in the study area. Loamy sand textural class was found to be more dominant over sandy loam at Lokaleng. The predominant class was sandy loam at Moshawane, while at Tsetse all samples were sandy loam. These soil textural classes fall under the Hutton soil, that is characterized being well drained hence provide excellent to moderate cultivation opportunities (Soil Classification, 1991). Hutton soils have a very weak structure which breaks easily upon the impact of rain drops, vehicular traffic and wind (Materechera & Medupe, 2006).

Soil pH- In all villages, topsoils exhibited higher soil pH than subsoils. The mean soil pH at Lokaleng was 7.13 and 6.58 for topsoil and subsoil, respectively. The soil pH range was 5.63 – 8.02 and 5.41-5.63 for topsoil and subsoil, respectively. The mean soil pH at Moshawane was 6.73 and 6.18 for topsoil and subsoil, respectively, while the range was 4.54 -8.26 and 3.84-8.34 for topsoil and subsoil, respectively. The mean soil pH for Tsetse was 7.20 for both topsoil and subsoil with the range of 6.39-7.86 and 5.27-7.99 for topsoil and subsoil, respectively. The lowest soil pH for both topsoil and subsoil in all villages was obtained for the controls.

Organic carbon- The mean soil %OC was higher in topsoil than subsoil for all villages. Tsetse village had the highest mean soil %OC, followed by Lokaleng and then Moshawane. The mean soil %OC at Lokaleng was 1.10% and 0.65% for topsoil and subsoil, respectively. The range was 0.48%-2.75% and 0.31%-0.91% for topsoil and subsoil, respectively. The mean soil %OC at Moshawane was 0.90% and 0.60% for topsoil and subsoil, respectively, while the range was 0.40%-2.24% and 0.38%-1.26% for topsoil and subsoil, respectively. The mean soil %OC for Tsetse was 1.75% and 1.74 % for both topsoil and subsoil with the range of 0.65%-2.82% and 0.61%-2.21% for topsoil and subsoil, respectively. The lowest soil %OC for both topsoil and subsoil in all villages were obtained for the controls.

Organic matter- The mean soil %OM was higher in topsoil than subsoil for all villages. Tsetse village had the highest mean soil %OM, followed by Lokaleng then Moshawane. The mean %OM at Lokaleng was 1.97% and 1.12% for topsoil and subsoil, respectively. The range was 0.83%-4.73% and 0.67%-1.57% for topsoil and subsoil, respectively. The mean %OM for Moshawane was 1.55% and 1.03% for topsoil and subsoil, respectively, while the range was 0.68%-3.85% and 0.65%-2.17% for topsoil and subsoil, respectively. The mean %OM at Tsetse was 3.02% and 2.99% for topsoil and subsoil, respectively, while the range was 1.11%- 4.85% and 1.04%-3.8% for topsoil and subsoil, respectively. The lowest soil %OM for both topsoil and subsoil in all villages were obtained for the controls.

Available phosphorus- The mean available P was higher in topsoil than subsoil for all villages. The mean available P at Lokaleng was 359 ppm and 120 ppm for topsoil and subsoil, respectively. The range was 47 ppm-616 ppm and 14 ppm-560 ppm for topsoil and subsoil, respectively. The mean available P for Moshawane was 559 ppm and 341 ppm for topsoil and subsoil, respectively with the range of 35ppm- 3430 ppm and 14 ppm-1610 ppm for topsoil and subsoil, respectively . The mean available P at Tsetse was 286 ppm and 105 ppm for topsoil and subsoil, respectively, while the range was 130 ppm-644 ppm and 39 ppm -252 ppm for topsoil and subsoil, respectively. The lowest soil available P for both topsoil and subsoil in all villages was obtained for the controls.

Total Nitrogen %- The mean total %N at Lokaleng was 0.11% and 0.10 % and for topsoil and subsoil, respectively. The range was 0.09%-0.19% and 0.08%-0.17% for topsoil and subsoil, respectively. The mean total %N at Moshawane was 0.09% and 0.08% for topsoil and subsoil, respectively, while the range was 0.05%-0.18% and 0.05%- 0.10% for topsoil and subsoil, respectively. The mean total %N for Tsetse was 0.12% and 0.11% for topsoil and subsoil, respectively, with the range of 0.09%-0.16% and 0.1%-0.15% for topsoil and subsoil respectively. There was no discernable difference in total %N between topsoil, subsoil and the controls for all villages.

Extractable K- The mean extractable K at Lokaleng was 276 ppm and 254 ppm for topsoil and subsoil, respectively. The range was 202 ppm-350 ppm and 202 ppm-355 ppm for topsoil and subsoil, respectively. The mean extractable K content values at Moshawane was 216 ppm and 183 ppm for topsoil and subsoil, respectively, while the ranges were 7.3 ppm -398 ppm and 6.2 ppm-387 ppm for topsoil and subsoil, respectively. The extremely low K values in the Moshawane analysis may have been due to blocking of the spectrophotometer suction tube during analysis. This would have led to an underestimate of the mean K for Moshawane. The mean extractable K for Tsetse was 133 ppm and 153 ppm for topsoil and subsoil, respectively, with the range of 70 ppm-191 ppm and 59 ppm-256 ppm for topsoil and subsoil, respectively. There was no discernable difference in extractable K between topsoil, subsoil and the controls for all villages.

Table 4.1 Means, maximums and minimums of the measured soil parameters for AILV growth areas in the three villages

	Lokaleng		Moshawane		Tsetse	
Parameter	**Topsoil**	**Sub soil**	**Topsoil**	**Sub soil**	**Topsoil**	**Sub soil**
Soil Ph						
Mean	7.13	6.58	6.73	6.18	7.20	7.20
Maximum	8.02	7.52	8.26	8.34	7.86	7.99
Minimum	5.63	5.41	4.54	3.84	6.39	5.27
Control	5.53	5.54	5.73	5.80	5.93	6.35
Organic Carbon %						
Mean	1.10	0.65	0.90	0.60	1.75	1.74
Maximum	2.75	0.91	2.24	1.26	2.82	2.21
Minimum	0.48	0.31	0.40	0.38	0.65	0.61
Control	0.38	0.35	0.49	0.54	0.76	0.79
Organic Matter %						
Mean	1.97	1.12	1.55	1.03	3.02	2.99
Maximum	4.73	1.57	3.85	2.17	4.85	3.80
Minimum	0.83	0.67	0.68	0.65	1.11	1.04
Control	0.66	0.61	0.85	0.93	1.30	1.36
Available P						
Mean	359	120	559	341	286	105
Maximum	616	560	3430	1610	644	252
Minimum	47	14	35	14	131	39
Control	0.56	0.52	0.49	0.39	0.42	0.53
Total Soil N (%)						
Mean	0.11	0.10	0.09	0.08	0.12	0.11
Maximum	0.19	0.17	0.18	0.10	0.16	0.15
Minimum	0.09	0.08	0.05	0.05	0.09	0.10
Control	0.14	0.11	0.1	0.11	0.11	0.10
Exchangeable K (ppm)						
Mean	276	258	216	183	133	153
Maximum	355	350	398	387	191	256
Minimum	202	202	7	6	70	59
Control	251	249	236	239	271	289

4.4 Discussions and conclusions

The data collected show that *Amaranthus* spp, *C. gynandra and C. album* grow in loamy sand and sandy loam textural classes (Hutton soil type). This is the most prevalent soil type in the study area. According to Soil Classification (1991), Hutton soils are described based on the presence of an apedal (structureless) "red" B-horizon. Hutton soils have a very weak structure which breaks easily upon the impact of rain drops, vehicular traffic and wind (Materechera & Medupe, 2006). Hutton soils are among the most important agricultural soils due to the deep, well-drained nature of these soils which provide excellent to moderate cultivation opportunities for various plants (Soil Classification, 1991).

The results of the study established that the soil pH of AILV growth areas for all three villages ranged from 4.54-8.26 for topsoils and 5.27–8.34 for subsoils. In all villages, the topsoil pH was higher than the subsoil pH. It was also established that the mean soil pH values for topsoils and subsoils were higher than their controls in each village. This study established that the range in topsoil pH where *Amaranth, C. gynandra and C. album* grow is 6.73-7.02. This is near the suggested soil pH range of 6.50 – 7.00 for most crops (Beaton, 1993).

Generally, the results indicated that the concentration of both %OC and %OM were higher in topsoils than in subsoils. This same trend was observed for both since %OM is estimated from the %OC. The highest %OM was observed at Tsetse, with a mean of 3.02% and 2.99%) for topsoil and for subsoil followed by Lokaleng (1.97% and 1.12%) and Moshawane (1.55% and 1.03 %), for topsoils and subsoils respectively. The content of both %OC and %OM were lower for the control sites in all the villages. Therefore, it is concluded that the soils associated with AILVs growth exhibited higher soil organic matter contents.

Organic matter is very significant in sustaining the productive capacity of soils. Organic matter increases soil CEC, supplies essential plant nutrients (nitrogen, phosphorus and sulphur), and promotes good soil structure, thereby improving water holding capacity (Greer and Schoenau, 1997). In this study, it was observed that AILV growth areas for soil analysis were sometimes located around garbage heaps in yards, nearby kraals, and sometimes in areas that previously held kraals. The higher %OM levels found in AILV growth soils may be attributed to this.

Soil nitrogen and phosphorus levels in sampled AILV growth soils were expected to be higher than the controls since higher %OM was observed in AILV growth soils in all villages. The results of the study established that available phosphorus was higher in sampled AILV growth areas than control areas for all villages. Soil phosphorus is the most deficient nutrient in most South African soils (van Averbeke & Yoganathan

2003), thus an increase in its availability will benefit AILV growth. However, it was established that total soil nitrogen was very low in all soils (AILV growth soils and the controls), with an average of 0.10 % total N. The mean soil nitrogen for the controls was within the range of soil nitrogen for AILV growth soils in all villages. This lack of differences between the controls and AILV growth soils for soil nitrogen in this study creates suspicion in the accuracy of N analysis, either with the age of chemicals or error by the researcher.

The results established that the mean soil extractable K for the controls was within the range of extractable K for AILV growth soils in all villages. Therefore, there was no difference in soil extractable K between the controls and AILV growth area soils for topsoils and subsoils. The higher %OM levels found in AILV growth soils did not increase soil extractable K, indicating that soil organic matter is not a good source of potassium. It has been reported that manure potassium is considered to be immediately and completely available to plants (Fulhage, 2000). This potassium will be leached from sandy soils (such as the Hutton soil) in a short period of time leaving organic matter in the soil which is bereft of potassium. The mean extractable K at Tsetse was lower than the mean extractable K at Lokaleng and Moshawane.

In conclusion, the study has established that *Amaranthus* spp, *C. gynandra and C. album* grow well in soils with high organic matter. This may be attributed to the higher %OM and higher available phosphorus in AILV growth soils. Therefore, the study suggests that organic matter addition to soils may increase AILV growth and may be used as a fertilizer for the domestication of AILVs.

CHAPTER 5

EFFECT OF CATTLE MANURE AND HARVESTING FREQUENCY ON THE GROWTH AND YIELD OF *CLEOME GYNANDRA*.

5.1 Introduction

Spider plant (*Cleome gynandra*) is one of the most significant indigenous wild leafy vegetables in Africa. The plant belongs to the Capparaceae family. It is an erect herbaceous plant with a height ranging from 0.5 m to 1.5 m depending on the environment in which it is cultivated (Faber *et al.*, 2007). In some instances, the plant is found growing under the shade of acacia erioloba and forb trees. The plant grows for a short period, hence the cutting of leaves is usually done once. The leaves of spider plant are mainly boiled and consumed as a green vegetable or dried to be used for future consumption as a relish with sorghum or maize meal porridge. The boiled sap is drunk by some people as it assumed to possess medicinal properties. The leaves are bitter, thus at times they are cooked together with other leafy vegetables such as amaranth or cowpea. The youngest leaves are usually gathered due to their ease of harvest, tenderness and high nutrition. They are also more appealing since they lack the insect damage of older leaves. Older leaves accumulate more dust and require more washing during preparation than younger leaves. Harvesting is usually done by women. Some communities sell dried leaves of *C. gynandra*, thus it also plays an important role in such communities by improving the economic status of villagers

Groeneveld *et al.* (2009) indicated that AILVs have a high potential for domestication since they are adapted to harsh environments and generally require simpler technologies and less inputs to grow than exotic vegetables. Stevens *et al.* (2008a) also support the latter by indicating that AILVs are easy to cultivate with minimal management. The documentation of AILVs, especially on agronomic aspects, is scant; therefore, this motivates for research in such areas. Studying agronomic or husbandry practices of AILVs is crucial in determining methods to increase yields of these plant species. For this study, cattle manure fertilization and harvesting frequency were studied as husbandry practices that influence the growth and yield of AILVs.

Cattle manure fertilization is a widely used husbandry practice among small scale farmers in South Africa. Chen *et al.* (2009) emphasized that cattle manure is a valuable fertilizer and contains a variety of plant nutrients that are recycled in agronomic systems for the production of food and fibre for humans and feed for livestock. Inorganic fertilizers are expensive for small scale-farmers in South Africa; hence, the use of manure will continue to play a very significant role in the maintenance of soil fertility (Materechera & Mkhabela, 2003). This is also supported by Girma, Haque & Lupwayi (2000), who stated that continuous cultivation of land is resulting in a decline of soil fertility in most agricultural systems in sub-Saharan Africa. Since most small-scale farmers cannot afford inorganic fertilizers, livestock manure (particularly cattle) becomes a key tool that could be useful in reversing this trend.

Harvesting frequency is one of the agronomic aspects that can be manipulated to increase the growth and yield of leafy crops. Generally, practices such as pruning or frequent cutting in vegetables encourage regrowth in leafy vegetables. However, it must be understood that regrowth depends on the crop(s). Therefore, harvesting frequency as a way of increasing growth and yield may be beneficial only for certain plant species. The objective of this study was to determine the effect of cattle manure and harvesting frequency on growth and yield of *C. gynandra* (one of three identified commonly used AILVs in the rural areas of Mafikeng).

5.2 Materials and Methods

5.2.1 Study area

The study was conducted at Molelwane farm, School of Agriculture at NorthWest University (Mafikeng campus). The farm is located along the Ramatlabama main road to Botswana, 8 Km from Mafikeng City, which lies approximately 25° 48'S and 25° 38'E. According to Materechera & Medupe (2006), Mafikeng is a typical semi-arid area, characterized by unreliable rainfall, with an annual mean of 550 mm (Materechera & Modiakgotla, 2006). Vegetation in the area is composed of grasses with scattered shrubs and bushes which are mostly acacia species. The area has dry cool winters with a minimum temperature range of 7-11.4 °C and hot summers with a maximum temperature range from 26.9 °C in June to 37 °C in January (Materechera & Modiakgotla, 2006). The soil in the area is described as a Hutton soil. Hutton soils are among the most important agricultural soils due to the deep, well-drained nature of these soils which provide excellent to moderate cultivation opportunities. Hutton soils are identified based on the presence of an apedal (structureless) "red" B-horizon (Soil Classification, 1991). Hutton soils have a very weak structure which breaks easily upon the impact of rain drops, vehicular traffic and wind (Materechera & Medupe, 2006).

5.2.2 Soil and cattle manure collection and preparation

Hutton soil was collected from an uncultivated area along the outskirts of the Molelwane farm. The soil was allowed to air-dry for one week prior to sieving (2 mm). Composted cattle manure was collected from the Molelwane farm and allowed to air-dry for one week. The manure was also sieved through a 2 mm screen. Subsequently, soil (6.2 kg) and cattle manure were thoroughly mixed and placed in 25 cm diameter PVC pots. Cattle manure application rates were C1 (0 ton ha^{-1}), C2 (15 tons ha^{-1}), C3 (30 tons ha^{-1}) and C4 (45 tons ha^{-1}). The method of mass of furrow slice was used to determine manure application. The amounts 0, 37.5 g, 75 g and 112 g were applied respectively for 0 ton ha^{-1}, 15 tons ha^{-1}, 30 tons ha^{-1} and 45 tons ha^{-1} application rates. Three methods of harvesting based on frequency were as follows; W1 (weekly), W2 (bi-weekly) and W3 (harvesting at the termination of experiment).

5.2.3 Seedlings establishment and transplanting

Seeds of *C. gynandra* were sown (04/02/2010) directly in seedling trays using Hygrotech$^+$ growing media and watered daily. Seeds emerged within four days of sowing (08/02/2010). Two seedlings were transplanted per pot (22/02/2010).

5.2.4 Experimental design

A factorial experiment of 4 x 3 combinations was arranged in a randomized complete block design (RCBD). Treatment combinations consisted of four manure levels (C1 –

C4), and three harvesting frequencies (W1 - W3). Treatments were replicated four times giving a total number of 48 pots. (See appendix 10).

5.2.5 Data collection

Plant data collection

Data collection commenced two weeks after transplanting (10/03/2010) and was conducted weekly thereafter. The parameters measured were plant height, number of leaves, dry weight and root length. Plant height was measured by taking the average height of the two plants in each pot. The number of leaves was determined by counting all the leaves from two plants per pot and thereafter taking the average for the two plants. Dry weight was determined by cutting leaves of the two plants per pot while leaving four remaining leaves (the leaves were from various plant branches) to allow continued photosynthesis and regrowth. Harvested leaves were then oven dried at 60 °C for 72 hours to determine dry mass yield. The average dry mass yield was calculated for the two plants in each pot. Root length was measured only at the termination (21/04/2010) of the experiment where the average root length for the two plants per pot was determined. The root lengths were determined by carefully removing the soil around the roots and measuring the length of the longest taproot.

Soil data collection

The soil was analyzed at the beginning and at the completion of the study. The distribution of soil particle sizes (soil textural class) was measured using the hydrometer method (Bouyoucos, 1951). Soil pH was determined on a saturated soil paste (Miller, 1992). Organic carbon and organic matter percentages were determined using the Walkley-Black method (Nelson & Sommers, 1982). Available phosphorus was determined using the Bray-1 method with subsequent spectrometer analysis (Dean & Olsen, 1965). Total nitrogen was determined by a micro-Kjeldahl procedure (Anderson & Ingram, 1993). Extractable potassium was determined using ammonium acetate extractant with subsequent analysis utilizing atomic absorption spectroscopy (Barnard *et al.*, 1990). Refer to Appendix 2 for complete soil analysis procedures.

Cattle manure

Cattle manure was analyzed for total nitrogen, available phosphorus, and extractable potassium utilising the same procedures as for soil analysis. Organic matter was determined by the ignition method (Gathua *et al.,* 1993). The sample was ignited slowly in a muffle furnace to a final temperature of 550°C. The loss in weight represents the moisture and organic matter while the residue represents ash. A 10 g manure sample was heated in a furnace at 550 °C and the organic matter and ash calculated by the differences before and after combustion (Gathua *et al.,* 1993).

5.2.6 Statistical analysis

Data was analyzed by Statistical Analysis System (SAS) and all data collected were subjected to ANOVA. The differences between means were compared using the Tukey method.

The linear model for factorial treatment design is:

$$Y_{ijk} = \mu + r_i + a_k + b_l + (ab)_{kl} + e_{ijk}$$

Where,

Y_{ijk} is the observation from the j^{th} block, cattle manure and harvesting frequency treatment combination,

μ is the general mean,

r_j is the j^{th} level of block effect,

a_k is the k^{th} level of cattle manure effect,

b_l is the l^{th} level of harvesting frequency effect,

$(ab)_k$ is the treatment cattle manure with harvesting frequency interaction effect,

e_{ijk} is the experimental error

5.3 Results

5.3.1 Effects of manure application and harvesting frequency on yield and growth parameters

Manure application rates had a significant effect on yield and growth parameters, while harvesting frequency had a significant effect only on dry weight (yield) and not on all other parameters as shown in the summary of analysis of variance (ANOVA) (See Appendix 11). Data recorded from this experiment showed that the interaction effect of manure application rate and harvesting frequency was not significant. The results also indicate blocking had an effect of some growth and yield parameters measured.

Yield- Data recorded from this experiment showed that manure application rates significantly improved yield /dry weight (Table 5.1). The highest yield (1.74 g/pot) was obtained with 45 tons ha^{-1}; however, this was not significantly greater than the yield obtained at 30 tons ha^{-1} (1.51 g/pot). The lowest yield (0.69 g/pot) was obtained when no manure was applied. The effect of harvesting frequency was significant on dry weight. The highest yields were recorded for weekly (1.69 g/pot) and bi-weekly (1.62 g/pot) harvesting, which were approximately three times greater than with a single harvest at the termination of experiment (0.53 g/pot).

Table 5.1 Effect of manure application rates and harvesting frequency on dry weight/ yield (g/pot)

Harvesting frequency	**Manure application rate (tons ha^{-1})**				**Harvesting effect**
	0	**15**	**30**	**45**	
Weekly	0.84	1.64	2.00	2.30	1.69 ^{a}
Bi-weekly	0.92	1.50	1.94	2.14	1.62 ^{a}
At termination	0.31	0.44	0.60	0.78	0.53 ^{b}
Manure effect	0.69 ^{a}	1.19 ^{b}	1.51 ^{bc}	1.74 ^{c}	
	Manure effect		**Harvesting effect**		
SE	0.11		0.09		
HSD (α 0.05)	0.41		0.33		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Leaf number- Manure application rates had a significant effect on leaf number (Table 5.2). The highest leaf numbers were obtained when 45 tons ha^{-1} and 30 ton ha^{-1} manure was applied (180 and 173 respectively). The lowest leaf number was recorded when 0 ton ha^{-1} and 30 tons ha^{-1} manure were applied (115 and 143 respectively). There was no significant difference for plant leaf number due to harvesting frequency.

Plant height- There was no significant difference in average plant height (Table 5.3) for manure application rates of 0, 15 and 30 tons ha^{-1} (43 cm, 49 cm and 51.2cm respectively). The greatest plant height (55.1cm) was recorded for 45 tons ha^{-1}; however, it was not significantly different from that of 15 and 30 tons ha^{-1}. There was no significant difference for plant height due to harvesting frequency.

Table 5.2 Effect of manure application rates and harvesting frequency on leaf number.

Harvesting frequency	**Manure application rate (tons ha^{-1})**				**Harvesting effect**
	0	**15**	**30**	**45**	
Weekly	109	141	166	160	144^{a}
Bi-weekly	113	137	163	183	149^{a}
At termination	123	152	191	197	166^{a}
Manure effect	115^{a}	143^{a}	173^{b}	180^{b}	
	Manure effect		**Harvesting effect**		
SE	7.6		6.6		
HSD (α 0.05)	28.8		22.7		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Table 5.3 Effect of manure application rates and harvesting frequency on plant height (cm).

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	43.5	50.4	43.9	54.1	48.0 [a]
Bi-weekly	42.9	44.0	54.0	51.2	48.0 [a]
At termination	43.7	52.5	55.6	60.2	53.0 [a]
Manure effect	43.3 [a]	49.0 [ab]	51.2 [ab]	55.1 [b]	
	Manure effect		Harvesting effect		
SE	2.5		2.2		
HSD (α 0.05)	9.5		7.6		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey'mms Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Root length- The results indicated that neither manure application rates nor harvesting frequency significantly influenced root length (Table 5.4).

Table 5.4 Effect of manure application rates and harvesting frequency on root length (cm)

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	20.0	22.1	22.4	22.5	21.8 [a]
Bi-weekly	15.9	20.5	19.5	19.1	18.8 [a]
At termination	16.3	28.4	22.5	20.3	21.8 [a]
Manure effect	17.4 [a]	23.7 [a]	21.5 [a]	20.6 [a]	
	Manure effect		Harvesting effect		
SE	1.8		1.5		
HSD (α 0.05)	6.7		5.3		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

5.3.2 Effects of manure application and harvesting frequency on soil properties

Soil and manure properties before planting.

The properties of soil and manure before planting are given in Table 5.5

Table 5.5 Properties of soil and manure used at the beginning of the study.

Analysis	Soil	Manure
Particle size distribution		
Sand 2 mm-0.053	74.4%	na
Silt 0.053- 0.002	11.8%	na
Clay <0.002	14.8%	na
Textural class	Sandy loam	na
pH (saturation)	7.14	na
Organic carbon (%)	0.53	na
Organic matter (%)	0.91	33
Ash	na	67
Phosphorus (ppm)	17.5	1027
Nitrogen (%)	0.14	0.84
Extractable Potassium (ppm)	314	
Extractable Potassium (%)		0.05

na= not applicable

Properties of soil at the end of the study due to various manure application rates and harvesting frequency.

Manure application rates had a significant effect on soil pH, organic carbon, organic matter, available phosphorus but not on total nitrogen and extractable K. Harvesting frequency did not have a significant effect on any of the above soil properties as shown in the summary of analysis of variance (ANOVA) (See Appendix 12). The interaction effect of manure application rate and harvesting frequency on soil properties was not significant.

Soil pH- The original soil pH was 7.14 (Table 5.5). The lowest soil pH level (7.46) was recorded when no manure was applied. Soil pH increased with increasing manure application rates (Table 5.6). The highest soil pH levels were recorded at 30 tons ha^{-1} (7.83) and 45 tons ha^{-1} (7.89) which were statistically equivalent.

Soil carbon – Manure application effect on soil carbon is given in Table 5.7. The original soil carbon was 0.53% (Table 5.5). There was no change in soil carbon at 0 ton/ha manure application rates. Soil carbon increased with increasing manure application rates; however, the increase was not significantly different for the 30 tons ha^{-1} and 45 tons ha^{-1} application rates.

Table 5.6 Effect of manure application levels and harvesting frequency on soil pH

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	7.44	7.65	7.82	7.89	7.70^{a}
Bi-weekly	7.47	7.64	7.85	7.84	7.70^{a}
At termination	7.48	7.68	7.83	7.93	7.70^{a}
Average Manure effect	7.46^{a}	7.65^{b}	7.83^{c}	7.89^{c}	
	Manure effect		**Harvesting effect**		
SE	0.05		0.04		
HSD (α 0.05)	0.18		0.14		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Table 5.7 The effect of manure application rates and harvesting frequency on soil carbon (%)

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	0.51	0.69	0.75	0.74	0.67^{a}
Bi-weekly	0.54	0.59	0.75	0.72	0.65^{a}
At termination	0.52	0.63	0.68	0.72	0.64^{a}
Manure effect	0.53^{a}	0.64^{ab}	0.73^{b}	0.73^{b}	
	Manure effect		**Harvesting effect**		
SE	0.03		4.17		
HSD (α 0.05)	0.12		0.09		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Soil organic matter- Soil organic matter content increased with increasing manure application rates (Table 5.8). The original soil organic matter content was 0.91% (Table 5.5). There was no change in soil organic matter at both 0 ton/ha (0.90%) and 15 ton/ha (1.04%) application rates. However, soil organic matter significantly increased at the 30 tons ha^{-1} (1.25%) and 45 tons ha^{-1} (1.25%) rates.

Table 5.8 The effect of manure application rates and harvesting frequency on soil organic matter (%)

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	0.88	1.03	1.28	1.27	1.11 [a]
Bi-weekly	0.93	1.01	1.30	1.24	1.12 [a]
At Termination	0.90	1.09	1.18	1.24	1.10 [a]
Manure effect	0.9 [a]	1.04 [a]	1.25 [b]	1.25 [b]	
	Manure effect		**Harvesting effect**		
SE	0.05		0.03		
HSD (α 0.05)	0.20		0.15		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Available phosphorus- The original available soil phosphorus level was 17.5 ppm (Table 5.5). Available soil phosphorus increased with increasing manure application rates (Table 5.9). The lowest available phosphorus levels were observed at manure application rates of 0 ton ha^{-1} (42 ppm) and at 15 tons ha^{-1} (59 ppm). The highest soil phosphorus levels were observed at manure application rates of 30 tons ha^{-1} (85 ppm) and 45 tons ha^{-1} (97 ppm) which were statistically equivalent.

Table 5.9 The effect of manure application rates and harvesting frequency on available phosphorus (ppm)

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	35	56	94	97	70[a]
Bi-weekly	40	59	83	88	68[a]
At termination	50	62	77	105	74[a]
Manure effect	42[a]	59[a]	85[b]	97[b]	
	Manure effect		Harvesting effect		
SE	4.82		4.17		
HSD (α 0.05)	18.4		14.4		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Total nitrogen - The results of this study (Table 5.10) established that all treatments did not have a significant effect on total soil nitrogen.

Table 5.10 The effect of manure application rates and harvesting frequency on total soil nitrogen (%).

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	0.10	0.10	0.10	0.10	0.10[a]
Bi-weekly	0.08	0.10	0.10	0.28	0.14[a]
At termination	0.09	0.09	0.10	0.10	0.09[a]
Manure effect	0.09[a]	0.10[a]	0.10[a]	0.16[a]	
	Manure effect		Harvesting effect		
SE	0.03		0.03		
HSD (α 0.05)	0.12		0.1		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

Extractable K - Extractable K remained statistically the same with increasing manure application rates and with harvesting frequency (Table 5.11)

Table 5.11 The effect of manure application rates and harvesting frequency on total soil extractable potassium (ppm).

Harvesting frequency	Manure application rate (tons ha^{-1})				Harvesting effect
	0	15	30	45	
Weekly	374	367	362	389	373 [a]
Bi-weekly	378	357	366	371	368 [a]
At termination	380	360	358	371	367[a]
Manure effect	377[a]	361[a]	361[a]	377 [a]	
	Manure effect		**Harvesting effect**		
SE	5.18		4.48		
HSD (α 0.05)	19.8		15.6		

Values are means ± S.E (n=48); Values in the same column (harvesting effect) bearing the same letter are not significantly different according to Tukey's Test. Values in the same row (manure effect) bearing the same letter are not significantly different according to Tukey's Test.

5.4 Discussion and conclusions

Growth and yield of *C. gynandra* improved with an increase of manure application rates. Similar yield and growth improvements by manure have been reported for other indigenous vegetables like *Solanum villosum* (Akundabweni *et. al.* (2003), *Amaranth* Chiveu & Opile, (2004), pumpkin (Azeez, Okorogbona & van Averbeke, 2009) and okra. Babatunde (2008) also found that cattle manure significantly increased okra stem girth, pod weight, pod length and pod diameter with the exception of plant height and number of leaves. The latter attributed this increase with the ability of manure to supply crop essential elements. Kimbi, Maerere & Nonga, (2001) also reported an increase in yield and root growth of *Amaranth* (*A. cruentus* L.) which they attributed to the increase in manure application.

Manure application rates resulted in significant increases in soil pH, organic carbon, organic matter, and available phosphorus, while harvesting frequency did not have a significant effect on any soil property. The observed growth and yield increase of *C. gynandra* in this study as a result of cattle manure addition to soil may be attributed to the concurrent increased levels of soil organic matter and available soil phosphorus. Materechera and Medupe (2006) highlighted that apart from supplying crops with nutrients, manure helps increase the organic matter content of the soil, as was observed in this study. This increased organic matter improves soil structure and water holding capacity, thereby providing a good environment for plant growth. Assefa *et al.* (1997) further emphasized that manures provide available carbon for soil microorganisms and thus stimulate microbial respiration, hence, increased microbial activity and populations. Therefore, increased microbial activity and populations, may implicate more decomposition of organic matter thus availing more nutrients to the plant.

The use of organic fertilizer improves soil productivity and fertility, which then improves yield and quality of crops (Joshy *et al.*, 2000). Similar results of soil property improvement were also reported by Babatunde, (2008) who observed a significant increase in organic carbon, pH, phosphorus, potassium, calcium and sodium with the use of cattle manure. Kimbi *et al.* (2001) also found out that soil available N and P significantly ($P < 0.05$) increased with increasing rate of manure application for each manure type (cattle manure inclusive).

Unexpectedly, there was no observed increase in total soil nitrogen with increased manure application rates. A similar observation was made by Alleh *et al.* (2003) where cattle manure application rates did not increase total soil nitrogen levels. They attributed low soil nitrogen levels to crop N uptake, immobilisation by microorganisms and nitrogen loss through volatilisation in conjunction with decreasing soil organic matter levels. However, this cannot be the cause of the unexpected soil N results in this study since soil organic matter increased with increased manure application rates and we would thus expect to observe a concurrent increase in total soil nitrogen. The lack of differences in total soil N results for the various manure application rates creates suspicion in the accuracy of N analysis, either with the age of chemicals or error by the researcher.

There was no significant change in extractable K with increasing manure application rates. A comparison of the control and manure treated soils indicates that the added manure did not provide much K to the soils. Lower extractable K might have been caused by the fact that the manure used in this study was exposed in the open prior to collection. This would have led to K loss from the manure since K is immediately and completely made available once mineralization begins (Fulhage, 2000).

An increase in soil pH was observed in this study. The same observation of an increase in soil pH with an increase in manure application rates was also made by Azeez, *et al.* (2009). Similarly, Christo *et al.* (2008) observed that manure (both poultry and cattle) application increased the pH of the soil after harvest. The effect of manure on soil pH is variable. Repeated applications of fertilizer N may lead to soil acidification while organic matter added as manure can act to help buffer the soil against a decrease in pH. This scenario therefore implies that addition of manure may lead to either pH increases or decreases depending on the rate of application and its chemical composition.

The results of this study indicate an optimum cattle manure application rate of either 30 tons ha^{-1} or 45 tons ha^{-1} since both rates give significantly the same yields, leaf numbers and plant heights. Apart from the effective increase on growth and yield of *C. gynandra,* the use of cattle manure is of great importance to villagers since it is cheap and locally available. Therefore, this can help rural villagers who cannot afford the cost of inorganic fertilizers. These results suggest that rural villagers can cultivate *C. gynandra* using cattle manure as a source of fertilizer.

Yield of *C. gynandra* improved when harvesting was done either weekly or bi-weekly. This was three times higher than the yield when harvested only at the termination of the study. Plants which were harvested at the termination of the experiment showed some yellowing of older leaves which eventually fell off while more frequent harvesting yielded green coloured leaves. The recommended harvesting frequency is bi-weekly since 1) it results in high yield, 2) it results in high quality leaves, and 3) it is more practical than weekly harvesting. The results of this study are in line with the findings of Materechera & Medupe (2006), who indicated that frequent (weekly) cutting encourages production of many leaves; however, does not allow the leaves sufficient time to grow resulting in low fresh weights and low dry weights of edible leaves. Materechera & Medupe (2006) also highlighted that harvesting frequency influenced leaf quality with a single harvest at the end of termination of the study resulting in coarse leaves. This quality is undesirable to consumers; therefore the latter recommended bi-weekly harvesting. Chiveu & Opile (2005) reported an increase in the total shoot number and length, leaf number and area (as some components of yield of the vegetable amaranth) when harvesting was done by pruning (frequent harvestings) as compared to when harvesting was done by uprooting. The latter therefore suggested that it would be more economical to grow and harvest amaranth under pruning. Additionally, Agbo *et al*. (2006) found out that among the urban and peri-urban areas of Cote d'Ivoire, most farmers harvest leafy vegetables by pruning so as to allow multiple harvests.

In conclusion, cattle manure is a valuable fertilizer resource to use for soil management for improved crop growth and is available to many rural farmers. The suggested application rate for the growth of *C. gynandra* is 30 tons ha^{-1} with a bi-weekly harvesting. Both of these parameters increased growth and yield of *C. gynandra* to the greatest extent while reducing inputs (both manure and time devoted to harvests) to optimal levels.

CHAPTER 6

GENERAL DISCUSSION AND CONCLUSIONS

Africa has a wide variety of wild indigenous leafy vegetables (AILVs) which are good sources of essential nutrients and can contribute to maintaining food security. The consumption of leafy vegetables brings numerous health benefits, and their everyday consumption is highly recommended since they are a source of vitamin C, folic acid, antioxidants, carotenoids and many other valuable chemicals (Łuczaj, 2010). AILVs can also play a key role in food security and possible income generation for rural communities. Although AILV utilisation provides many benefits, little attention has been given to these plant species in research and community usage. There are several factors or barriers that limit AILV usage and may potentially lead to their extinction. These include people's view of AILVs as a poverty crop and their fear of the possible toxic effects of AILVs if intake exceeds certain limits (Dovie *et al.*, 2007).

Abukutsa-Onyango (2007) highlighted that promoting the production and utilization of AILVs will ensure conservation by utilization, and that as long as there is consumer demand for AILVs then production will be sustained to meet the demand and therefore avoid the threat of their extinction. Hendriks *et al.*, (2006) emphasized the importance of education in improving knowledge of AILVs. There is a need to educate younger generations about the importance and benefits of AILVs. This will help to avoid the loss of valuable knowledge concerning AILVs.

The main objective of this study was to increase awareness of the importance and utilization of AILVs and the important role they can play in food security and also to determine baseline edaphic factors and husbandry practices for AILV growth so as to increase their productiveness if they are domesticated. The three parts of this study meet this overall main objective. Part one of this study used a survey as a tool to gather information on rural villagers' knowledge and usage of AILVs. Part two of the study investigated baseline soil parameters influencing the growth of commonly used AILVS in the study area (*Amaranthus* spp, *C. gynandra* and *C. album)*. Part three of the study investigated the effect of cattle manure and harvesting frequency on soil properties and subsequent yield and growth parameters of *Cleome gynandra*.

Villagers' knowledge and utilization of AILVs

The results of part one of the study (Chapter 2) established that villagers have knowledge of AILVs. Villagers knew numerous AILVs that were included in the survey questionnaire (*Amaranthus* spp, *V. unguiculata, C. maxima C. gynandra* and *C. album*) as well as other AILVs that they mentioned using their local Tswana names (thoma, seropolane, motetejane, monyaku leshe and shepashepe). Villagers also verified their knowledge of AILVs by identifying AILVs pictorially. The most highly recognized AILVs by picture recognition were amaranth, *C. gynandra*, *V. unguiculata, C. maxima*. It was established that knowledge of AILVs did not necessarily mean that the villagers utilsed them. The three most commonly preferred AILVs in all studied communities were *Amaranthus* spp, *C. gynandra* and *C. album* Most respondents (67%) in all villages indicated a preference of AILVs in the presence of both AILVs and exotic vegetables; however, they mentioned that utilization is limited by short growth duration period and low rainfall. The results also indicated that AILV preference is not influenced by gender but by age. The majority of respondents (63%) for all villages in the < 20 year age group indicated a preference of exotic vegetables over AILVs, while other age groups indicated a preference of AILVs over exotic vegetables. People in this age group think that AILVs are primitive foods and that it is time consuming to go to the bush for vegetable gathering while exotic vegetables can be easily accessed from the shops (personal communication). This may eventually result in the extinction of AILVs knowledge.

A vast majority (94%) of villagers indicated that AILVs are used only for consumption purposes. A majority of respondents (77%) cited that they transfer AILVs knowledge to their children through their usage of AILVs. This transfer of knowledge through usage was higher in Lokaleng than in the other villages. As evidenced in this study, villagers are knowledgeable of harvesting methods. The majority of respondents (70%) reported leaf picking as a commonly used harvesting method. The villagers emphasized that this method does not hamper production of new leaves but rather increases production of new leaves. Respondents showed a strong dislike of the uprooting method since it significantly contributes to the extinction of AILVs. The method of uprooting was cited to be practised only by few respondents (3%) at Moshawane. Finally, this study determined that villagers, regardless of age or gender, do not have knowledge of soil parameters influencing AILVs growth. Respondents cited "any" or "don't know" (>75%) when asked to give any observation or knowledge on soil colour and type where AILVs are found.

It was established that villagers know and utilize AILVs; however, AILVs domestication by villagers was very negligible. Only 6% of villagers indicated that they cultivate AILVs, with 80% of these being from Tsetse village, mainly cultivating *V. unguiculata* along with exotic vegetables. In order to influence domestication of AILVs by farmers, this study recommends education on domestication of AILVs to villagers and also on agronomic aspects that can be used to increase their productivity if they are cultivated. However, this necessitates more information concerning the relationship between soil parameters and AILV growth. This need motivated for part two of this study.

Edaphic factors influencing growth of three commonly used AILVs *(Amaranth* spp, *C. gynandra and C. album) in the study area.*

Part two of this study (Chapter 4) evaluated several soil parameters and their association with AILV growth. The study established that *Amaranthus* spp, *C. gynandra and C. album* grow well in soils with more organic matter. This was confirmed by the higher %OM and higher available phosphorus in soils under AILV growth. The observance of kraals and rubbish heaps near the areas of soil sampling confirmed the importance of organic matter in promoting AILV growth. Soil pH analysis indicated a wide range of soil pH for AILV growth with topsoil pH ranging around 6.5 to 7.4. Therefore, the study suggests that organic matter addition to soils may increase AILV growth and may be used as a fertilizer for the domestication of AILVs, thus the motivation for the part three of this study.

The effect of cattle manure and harvesting frequency on yield of C. gynandra and on soil properties.

Research of husbandry practices that influence AILV growth will contribute to a better understanding of appropriate management practices for such plant species. Part three of this study (Chapter 5) investigated manure fertilization and harvesting frequency as husbandry practices for *C. gynandra*. An increase in manure application rates resulted in an increase in yield and growth parameters (dry weight, leaf number, plant height). An application rate of 30 tons ha^{-1} was recommended to give the optimum yield of *C. gynandra*. Harvesting frequency only had a significant effect on yield (dry weight). The highest yields (1.69 g/pot and 1.62 g/pot for 45 tons ha^{-1} and 30 tons ha^{-1}, respectively) were achieved when harvesting was done either weekly or bi-weekly. This yield was three times greater than a single harvest at the termination of the study (0.53 g/pot). Since weekly and bi-weekly harvesting resulted in significantly the same yields, bi-weekly harvesting is recommended since it allows the plant more time for re-growth.

It was concluded that a manure application rate of 30 tons ha^{-1} and bi-weekly harvesting produced an optimum yield of *C. gynandra*. The results also established that soil properties (soil pH, organic carbon, organic matter, and available phosphorus) increased with an increase in manure application. The observed growth and yield increase of *C. gynandra* in this study as a result of cattle manure application to soil may be attributed to the concurrent increased levels of soil organic matter and available soil phosphorus. In conclusion, cattle manure is a convenient and available fertilizer which farmers can use for the domestication of AILVs.

Need for further work/study

First, villagers used local names during the course of the survey study (Chapter 3) which were not known to the researcher. This made it difficult to identify specific plants. It would be very helpful to catalogue villagers' local names for AILVs in relation to their scientific names. This motivates for a further study to gather this information from villagers utilizing photos and dried plant samples to help in the identification.

Second, AILV knowledge may become extinct unless pro-action is taken. AILV knowledge resides with older people while younger people are more interested in utilizing exotic vegetables. The importance of AILVs needs to become part of agriculture curriculums at both high school and university levels.

Third, it was established that villagers have knowledge of AILVs and utilise AILVs grown in the wild; however, domestication of AILVs by villagers is very negligible. It is hoped that this study and future similar studies can provide valuable information and suggestions to promote AILVs domestication. As well, it is suggested that extension education for farmers include current research information on AILVs.

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APPENDICES

Appendix 1a - Survey questionnaire

Part 1 Demographic information

1. Age,

1. Under 20		2. 21-40		3. 41-60		4. Above 60	

2. Gender,

1. Female		2. Male	

3. Marital Status

1. Single		2. Married	

4. Level of education

1. Primary		2.Secondary	

5. Occupational status

1. Unemployed		2. Employed	

6. Numbers of years residing in that particular area

1. Under 5		2. 6-10		3. Over 10	

7. Do you know indigenous leafy vegetables?

1. Yes		2. No	

Any one who answers no to question 7 will not proceed to part 2 of the questionnaire!

8. **Part 2. Knowledge of AILVs by villagers**

	8.1	8.2		8.3
AILVs	Name AILVs you (Verbally) (√)	Evidence of AILVs you know (pictorially)		Three most important/ utilised AILVs using rank of 1-3, according to preference
*1.*Amaranth, Thepe		C	W	
2.Cochorus Olitorious, jute/ Delele		C	W	
3.Cleome gynandra, Rothwe/lerotho		C	W	
4.Cleome monophylla, Single-leaved cleome		C	W	
5. Vigna unguiculata, Cowpea/ dinawa		C	W	
6*Cucurbita maxima,* Pumpkin/lephutshe		C	W	
7.*Citrallus lanatus,* Melons/mokate		C	W	
8.Bidens pilosa, common black jack		C	W	
9.Chenopodium carinatum, green goosefoot		C	W	
10. Chenopodium album, white goosefoot/ fat hen		C	W	
11.*Chenopodium murale,* Nettle-leaved goosefoot		C	W	
12.Hypochoeris radicata		C	W	
*13.*Portulaca *oleracea,* purslane		C	W	
14. Urtica urens, annual nettle		C	W	
15.Emex australis, spiny emex, Mosetlho		C	W	
16.Lactuca serriola, prickly		C	W	
Others				

Key: C= Correct; W= Wrong

1. First choice 2. Second choice 3. Third choice

9. In presence of both conventional and AILVs what would you prefer?

1. conventional		2. AILVs	

10. Describe method of harvesting

1.leaves picking		2.leaf,stalk & Branches		3. Uprooting	

11. List any purpose you use the vegetables for.

1. Food		2.Food & Medicinal		3.Other	

12. Do you domesticate any AILV?

1. Yes		2. No	

14. Generally how can you rate utilization of AILVs by your society?

1.High		2.Average		3.Poor		4. Don't know	

15. Is there transformation or transfer of knowledge of AILVs within the community?

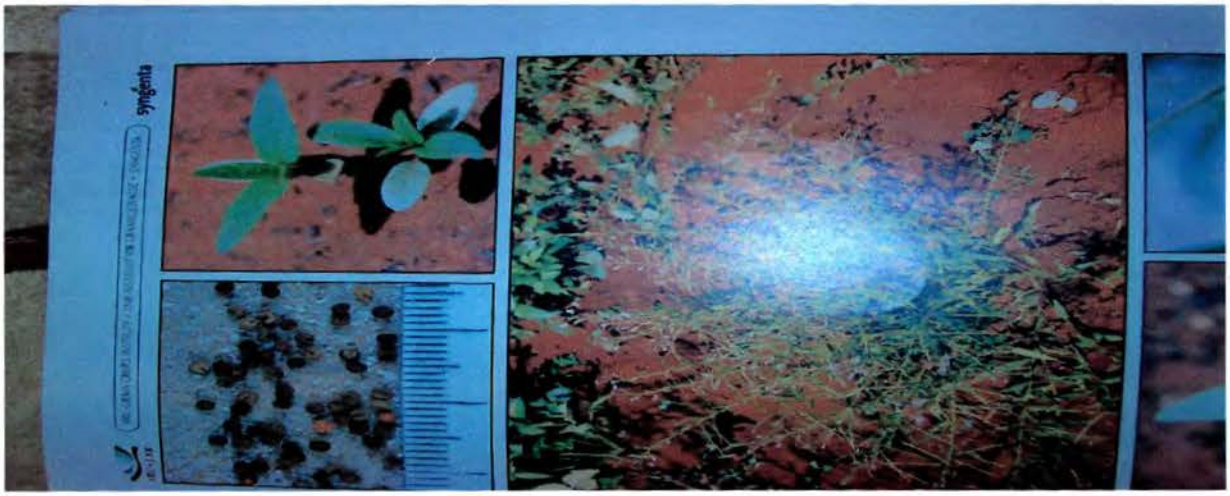
1.Yes		2.Partial		3.No		4.Don't know	

Appendix 1b PICTURES OF AILVs

1.

2.

3.



4.

5.

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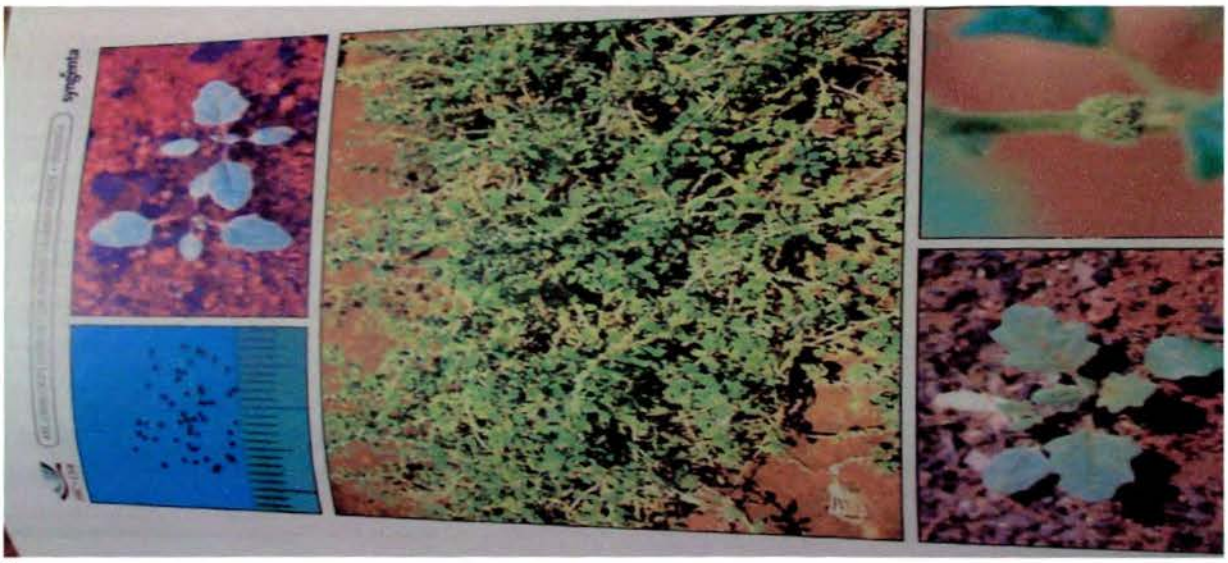
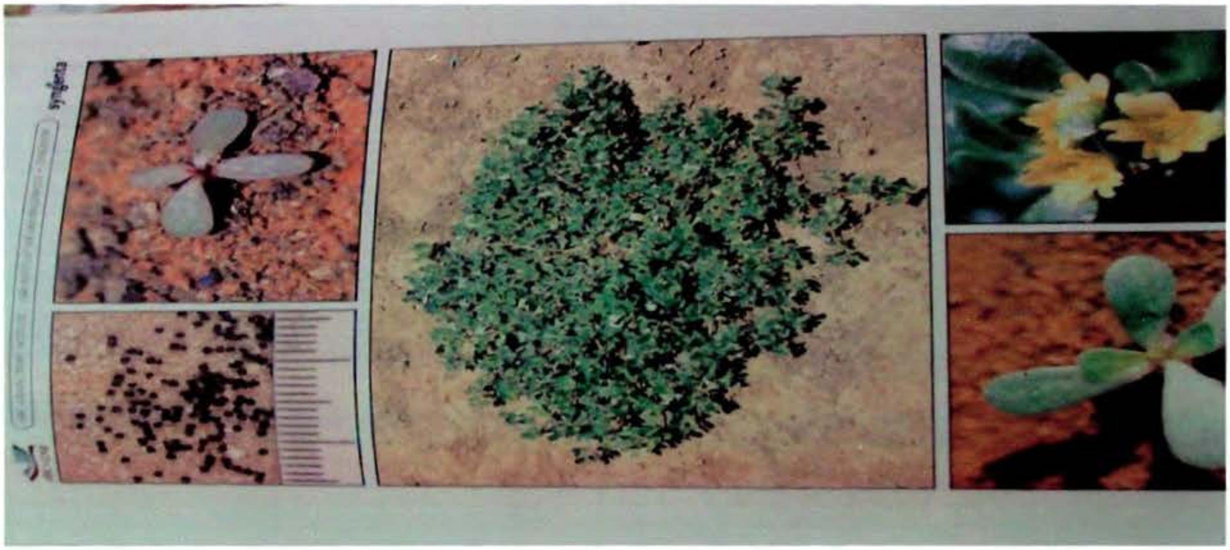


9.

10.

11.

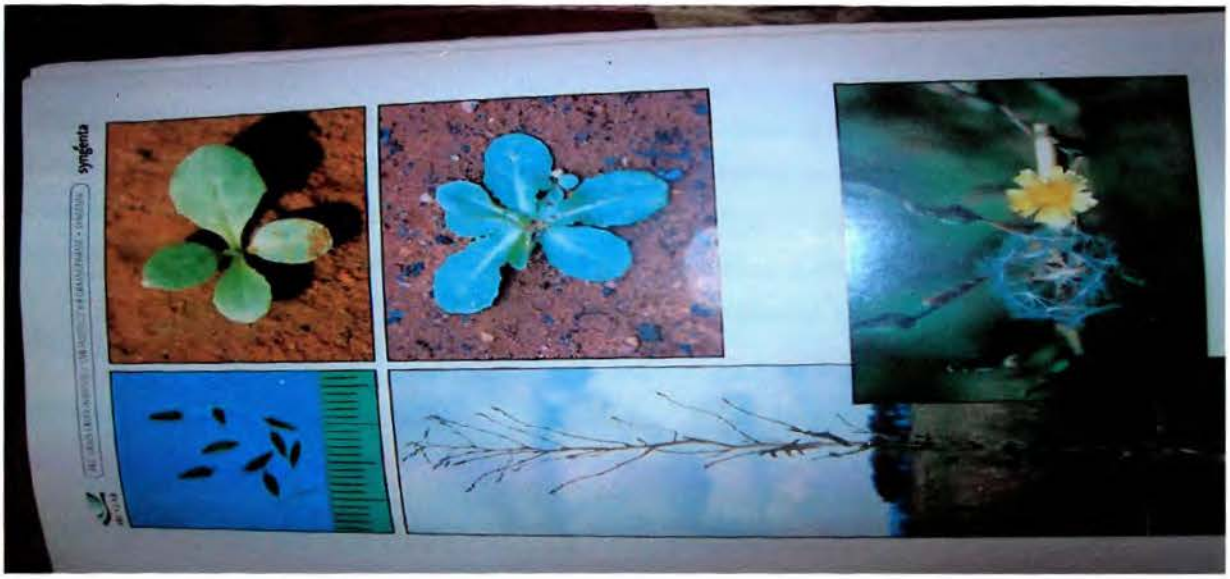
12



13

14.

15.



16.

Appendix 2

Soil analytical methods used in Chapters 4 and 5.

Particle size distribution (soil texture)

A 50 g sample of air dried soil passed through 2 mm sieve was dispersed in 10% calgon and the distribution of particle sizes was measured using the hydrometer method (Bouyoucos, 1951). A mechanical shaker was used to achieve complete dispersion. Soil texture was then obtained from the particle distribution results using a soil textural triangle.

Soil pH (Saturation)

Soil pH was measured in a saturated paste using a glass-calomel electrode. A 50 g sample of air dried soil passed through a 2 mm sieve was saturated with distilled water in a 50 ml beaker, stirring with a spatula. The soil was allowed to stand for one hour and the pH was measured by submerging the glass-calomel electrode in the saturated paste (Miller, 1992).

Organic carbon and organic matter

Organic carbon percentage was determined using the Walkley-Black method outlined by Walkley (Nelson and Sommers, 1982). A 1g air dried soil sample passed through a 0.35mm sieve was oxidized in 10 ml K_2Cr_2 O_2, and 20 ml sulphuric acid (H_2SO_4). The contents were allowed to cool. After thirty minutes 150ml distilled water and 10ml concentrated ortho-phosphoric acid were added. Organic carbon was determined by titration with an iron (II) ammonium sulphate solution utilising barium diphenylamine sulphonate as the indicator. The endpoint colour changed from dark violet brown to green. Organic matter was estimated from organic carbon by multiplying the organic carbon percentage value with 1.72.

Available phosphorus (P)

Available phosphorus was determined using the Bray-1 method (Dean & Sommers, 1965). A 1g soil sample was extracted with 7ml Bray-1 extraction solution (0.03N NH_4F and .025 N HCL). Phosphorus concentration was determined from the filtrate by the reduction of phosphomolybdic acid that yields an intense blue colour using a spectrophotometer at 660 nm wavelength. Standard stock solution was prepared by dissolving 4.394 g of dried (105°C) KH_2PO_4 in 1 litre distilled water, which was diluted to make the standards of 0, 1, 2, 3, 4 and 5µg P/ml.

Total nitrogen (N)

Total nitrogen was determined by a micro-Kjeldahl procedure (Anderson & Ingram, 1993). A 0.2 g soil sample was digested in 4.4 ml of digestion mixture: (0.42 g Selenium (catalyst), 14 g lithium sulphate, 350 ml of 30% hydrogen peroxide and 420 ml of concentrated sulphuric acid). Sodium hydroxide was then added to a 50 ml aliquot of the digestion sample and steam distilled to liberate ammonia. The ammonia was collected into a 5ml boric acid solution. Hydrochloric acid (0.00714 M) was used for titration with an endpoint colour change from yellow to pink using methyl red (PH 4.2 - 6.2)

Extractable potassium (K)

Extractable potassium (K) was extracted with 1 mol dm^{-3} ammonium acetate. Extractable K was determined by atomic absorption and flame spectrophotometer (Barnard *et al.*, 1990)

Appendix 3

Particle size distribution and soil texture of soils.

Lokaleng soil samples	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural class**
1.1	74.4	10	15.6	Sandy loam
1.2	84.4	4.0	11.6	Loamy sand
2	84.4	8.0	7.6.0	Loamy sand
3	76.4	12.0	11.6	sandy loamy
4	84.4	6.0	9.6.0	Loamy sand
5	82.4	8.0	9.6.0	Loamy sand
6.1	82.4	6.0	11.6	Loamy sand
6.2	76.4	12.0	11.6	Sandy loam
7.1	76.4	16.0	7.6	Sandy loam
7.2	80.4	12.0	7.6	Loamy sand
Comtrol1	80.0	12.0	8.0	Loamy sand
Control2	78.0	14.0	8.0	Sandy loam
Moshawane soil samples	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural class**
1.1	78.4	1.6	20.0	Sandy loam
1.2	76.4	15.6	8.0	Sandy loam
1.3	78.5	11.5	10.0	Sandy loam
2.1	78.5	11.5	10.0	Sandy loam
2.2	78.5	9.5	12.0	Sandy loam
2.3	86.4	5.6	8.0	Loamy sand
3.1	88.4	1.6	10.0	Loamy sand
3.2	84.4	5.6	10.0	Loamy sand
4	88.4	3.6	8.0	Loamy sand
5.1	76.4	13.6	10.0	Sandy loam
5.2	76.8	11.2	12.0	Sandy loam
6.1	74.4	11.6	14.0	Sandy loam
6.2	78.4	7.6	14.0	Sandy loam
Control1	76.0	23.0	1.0	Loamy sand
Control2	78.0	21.0	1.0	Loamy sand
Tsetse soil samples	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural class**
1.1	72.4	16.8	10.8	Sandy loam
1.2	72.4	18.8	8.8	Sandy loam
2	74.4	12.8	12.8	Sandy loam
3	72.4	18.8	8.8	Sandy loam
4	74.4	14.8	10.8	Sandy loam
5	72.4	16.8	10.8	Sandy loam
6.1	58.4	28.8	12.8	Sandy loam
6.2	84.4	0.80	14.8	Sandy loam
7	70.4	16.8	12.8	Sandy loam
Control1	78.0	14.0	8.0	Sandy loam
Control2	72.0	18.0	10.0	Sandy loam

Appendix 4

Soil pH for AILV growth areas per village (Chapter 4).

Lokaleng			Moshawane			Tsetse		
Sample	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**
1.1	7.67	7.52	1.1	6.78	5.84	1.1	7.51	7.2
1.2	6.64	6.79	1.2	6.26	6.74	1.2	6.49	6.89
2	6.66	7.01	1.3	8.26	8.34	2	6.39	5.27
3	5.63	6.37	2.1	6.12	7.82	3	7.59	7.99
4	8.02	6.98	2.2	7.98	8.22	4	7.74	7.73
5	7.72	5.76	2.3	7.64	5.35	5	7.86	7.73
6.1	7.25	5.41	3.1	6.62	4.87	6.1	7.23	7.74
6.2	7.25	5.41	3.2	6.66	5.93	6.2	6.47	6.85
7.1	7.15	7.45	4	4.54	3.84	7	7.55	7.48
7.2	7.27	7.09	5.1	8.25	4.97			
			5.2	7.12	6.4			
			6.1	6.57	6.39			
			6.2	6.68	6.36			
μ	7.13	6.58	**μ**	6.73	6.18	**μ**	7.20	7.20
Max	8.02	7.52	**Max**	8.26	8.34	**Max**	7.86	7.99
Min	5.63	5.41	**Min**	4.54	3.84	**Min**	6.39	5.27
C1	5.71	5.58	**C1**	5.83	5.67	**C1**	5.67	6.42
C2	5.35	5.49	**C2**	5.63	5.92	**C2**	6.19	6.27

μ=Mean, Max=Maximum, Min=minimum, C1=control 1, C2=control 2

Appendix 5

Organic carbon (%) in AILV growth areas per village (Chapter 4).

Lokaleng			Moshawane			Tsetse		
Sample	**Top soil**	**Sub Soil**	**Sample**	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**
1.1	0.50	0.52	1.1	0.97	0.91	1.1	1.09	1.66
1.2	0.48	0.54	1.2	2.24	0.50	1.2	1.98	1.62
2	1.16	0.90	1.3	1.65	0.45	2	1.40	1.70
3	0.75	0.79	2.1	0.60	0.42	3	1.78	1.76
4	0.53	0.39	2.2	0.40	0.38	4	1.92	2.21
5	0.59	0.53	2.3	0.50	1.26	5	2.82	2.19
6.1	1.17	0.58	3.1	1.10	0.53	6.1	1.99	1.70
6.2	0.93	0.45	3.2	0.92	0.54	6.2	2.17	2.18
7.1	2.75	0.89	4	0.71	0.57	7	0.65	0.61
7.2	2.14	0.91	5.1	0.42	0.51			
			5.2	0.59	0.56			
			6.1	0.85	0.63			
			6.2	0.77	0.57			
μ	1.1	0.65	**μ**	0.90	0.60	**μ**	1.75	1.74
Max	2.75	0.91	**Max**	2.24	1.26	**Max**	2.82	2.21
Min	0.48	0.31	**Min**	0.40	0.38	**Min**	0.65	0.61
C1	0.33	0.27	**C1**	0.45	0.44	**Cl**	0.61	0.74
C2	0.43	0.43	**C2**	0.54	0.64	**C2**	0.90	0.83

μ=Mean, Max=Maximum, Min=minimum, Cl=control 1, C2=control 2

Appendix 6

Organic matter (%) in AILV growth areas per village (Chapter 4).

Lokaleng			Moshawane			Tsetse		
Sample	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**
1.1	0.86	0.90	1.1	1.67	1.57	1.1	1.87	2.87
1.2	0.83	0.93	1.2	3.85	0.86	1.2	3.41	2.79
2	2.77	1.54	1.3	2.84	0.77	2	2.40	2.92
3	1.29	1.35	2.1	1.04	0.71	3	3.05	3.02
4	0.91	0.67	2.2	0.68	0.65	4	3.31	3.80
5	1.02	0.92	2,3	0.86	2.17	5	4.85	3.77
6.1	2.01	0.99	3.1	1.89	0.91	6.1	3.42	2.92
6.2	1.60	0.78	3.2	1.58	0.92	6.2	3.73	3.75
7.1	4.73	1.54	4	1.21	0.98	7	1.11	1.04
7.2	3.68	1.57	5.1	0.73	0.88			
			5.2	1.02	0.95			
			6.1	1.46	1.09			
			6.2	1.32	0.98			
μ	1.97	1.12	**μ**	1.55	1.03	**μ**	3.02	2.99
Max	4.73	1.57	**Max**	3.85	2.17	**Max**	4.85	3.80
Min	0.83	0.67	**Min**	0.68	0.65	**Min**	1.11	1.04
C1	0.57	0.47	**C1**	0.77	0.75	**Cl**	1.05	1.28
C2	0.74	0.75	**C2**	0.93	1.1	**C2**	1.55	1.43

μ=Mean, Max=Maximum Min=minimum value C1=control 1 C2=control 2

Appendix 7

Available phosphorus (ppm) in AILV growth areas per village (Chapter 4).

Lolakeng			Moshawane			Tsetse		
Sample	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub Soil**
1.1	235	65	1.1	35	1470	1.1	352	138
1.2	47	14	1.2	504	18	1.2	273	39
2	238	35	1.3	1715	511	2	173	39
3	616	560	2.1	140	26	3	247	53
4	434	112	2.2	47	103.3	4	294	130
5	140	46	2.3	3430	1610	5	131	147
6.1	483	44	3.1	308	74	6.1	168	41
6.2	499	23	3.2	273	40	6.2	294	110
7.1	546	147	4	196	504	7	644	252
7.2	350	152	5.1	189	14			
			5.2	280	28			
			6.1	67	25			
			6.2	86	14			
μ	359	120	**μ**	559	341	**μ**	286	105
Max	616	560	**Max**	3430	1610	**Max**	644	252
Min	47	14	**Min**	35	14	**Min**	130	38.5
C1	0.45	0.48	**C1**	0.5	0.48	**Cl**	0.48	0.50
C2	0.67	0.55	**C2**	0.48	0.3	**C2**	0.35	0.55

μ=Mean, Max=Maximum Min=minimum value C1=control 1 C2=control 2

Appendix 8

Total nitrogen (%) in AILV growth areas per village (Chapter 4).

Lokaleng			**Moshawane**			**Tsetse**		
Sample	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub Soil**
1.1	0.10	0.10	1.1	0.13	0.10	1.1	0.11	0.12
1.2	0.09	0.10	1.2	0.18	0.09	1.2	016	011
2	0.10	0.09	1.3	0.11	0.07	2	0.10	0.10
3	0.10	0.09	2.1	0.08	0.08	3	0.12	0.11
4	0.09	0.08	2.2	0.07	0.10	4	0.09	0.11
5	0.13	0.09	2.3	0.05	0.09	5	0.16	0.15
6.1	0.11	0.10	3.1	0.08	0.07	6.1	0.13	0.11
6.2	0.11	0.10	3.2	0.08	0.05	6.2	0.12	0.12
7.1	0.19	0.12	4	0.10	0.07	7	0.13	0.10
7.2	0.10	0.17	5.1	0.08	0.07			
			5.2	0.07	0.07			
			6.1	0.07	0.08			
			6.2	0.07	0.06			
μ	0.11	0.10	**μ**	0.09	0.08	**μ**	0.12	0.11
Max	0.19	0.17	**Max**	0.18	0.10	**Max**	0.16	0.15
Min	0.09	0.08	**Min**	0.05	0.05	**Min**	0.09	0.10
C1	0.18	0.10	**C1**	0.10	0.09	**C1**	0.11	0.09
C2	0.10	0.11	**C2**	0.10	0.13	**C2**	0.10	0.11

μ=Mean, Max=Maximum Min=minimum value C1=control 1 C2=control 2

Appendix 9

Extractable potassium (ppm) in AILV growth areas per village (Chapter 4).

Lokaleng			Moshawane			Tsetse		
Sample	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**	**Sample**	**Top soil**	**Sub soil**
1.1	302	260	1.1	398	387	1.1	153	151
1.2	269	263	1.2	259	161	1.1	146	143
2	272	255	1.2	251	352	2.1	155	256
3	286	325	2.1	280	152	3	98	59
4	330	308	2.2	281	57	4	78	78
5	330	350	2.3	125	357	5	191	213
6	355	202	3.1	325	279	6.1	165	156
6	202	204	3.2	239	262	6.2	143	159
7	206	206	4	225	70	7	70	166
7	208	207	5.1	227	234			
			5.2	179	60			
			6.1	10	8			
			6.2	7	6			
μ	276	258	**μ**	216	183	**μ**	133	153
Max	355	350	**Max**	398	387	**Max**	191	256
Min	202	202	**Min**	7.3	6.2	**Min**	70	59
C1	239	240	**C1**	214	218	**C1**	253	269
C2	262	258	**C2**	258	261	**C2**	288	308

μ=Mean, Max=Maximum Min=minimum value C1=control 1 C2=control 2

Appendix 10

Experimental lay-out

	R1				R2			R3			R4
C1W1	C2W3	C2W2	C2W2	C3W2	C4W3	C1W2	C1W3	C4W3	C3W3	C2W3	C2W1
C3W3	C1W3	C4W1	C3W1	C3W3	C4W2	C4W1	C4W2	C1W1	C2W2	C1W1	C4W3
C4W3	C2W1	C4W2	C2W3	C1W3	C1W2	C3W3	C2W2	C2W3	C1W3	C3W1	C4W2
C1W2	C3W1	C3W2	C4W1	C2W1	C1W1	C3W1	C3W2	C2W1	C4W1	C3W2	C1W2

Cattle Manure application rates
C1-0 t/ha
C2-15 t/ha
C3-30 t/ha
C4-45 t/ha

Interval of harvesting (Time)
W1- Weekly
W2- Fortnight
W3- Harvesting at experiment termination.

Appendix 11

ANOVA for dry weight, leaf number, plant height and root length

Parameters	Source of variance				
	Df	**SS**	**MS**	**F**	**Pr>F**
Dry weight					
Manure	3	7.5	2.5	20.9	<.0001***
Harvesting frequency	2	13.5	6.7	56.6	<.0001***
Block	3	1.2	0.4	3.4	0.0302*
Manure*Harvesting frequency	6	1.3	0.2	1.8	0.1232 ns
Error	33	3.9	0.1		
Total	47	27.4			
R-square= 0.86 CV=27 Root MSE=0.34					
Leaf number					
Manure	3	31807.2	10602.4	15.0	<.0001*
Harvesting frequency	2	4064.5	2032.3	2.9	0.0705 ns
Block	3	1432.6	477.5	0.7	0.5730 ns
Manure*Harvesting frequency	6	1458.5	243.1	0.3	0.9083 ns
Error	33	23313.7	706.5		
Total	47	62076.5			
R-square=0.62 CV=17.4 RMSE =26.6					
Plant height					
Manure	3	871.8	290.6	5.7	0.0030***
Harvesting frequency	2	266.7	133.3	2.6	0.0888 ns
Block	3	1077.2	359.1	7.0	0.0009***
Manure*Harvesting frequency	6	382.7	63.8	1.3	0.3080 ns
Error	33	1687.0	51.1		
Total	47	4285.4			
R-Square=0.61 CV= 14.4 RMSE=7.2					
Root length					
Manure	3	244.9	81.6	2.4	0.0828 ns
Harvesting frequency	2	99.1	49.5	1.5	0.2438 ns
Block	3	236.9	78.8	2.35	0.0904 ns
Manure*Harvesting frequency	6	127.5	21.2	0.63	0.7036 ns
Error	33	1109.5	33.6		
Total	47	1818.0			
R-Square=0.39 CV= 27.9 RMSE=5.8					

*=significant ***=highly significant ns=not significant α=0.05

Appendix 12

ANOVA for soil pH, organic carbon, organic matter, available phosphorus, total N and extractable K

Parameters	Source of variance				
	Df	**SS**	**MS**	**F**	**Pr>F**
Soil Ph					
Manure	3	1.345	0.448	22.95	<.0001 ***
Harvesting frequency	2	0.009	0.005	0.24	0.7874 ns
Block	3	0.271	0.090	4.63	0.0083*
Manure*Harvesting frequency	6	0.015	0.002	0.13	0.9924 ns
Error	33	0.645	0.020		
Total	47	2.285			
R-square= 0.72 CV=1.81 Root MSE=0.14					
Organic carbon (%)					
Manure	3	0.331	0.110	10.95	<.0001***
Harvesting frequency	2	0.007	0.004	0.36	0.7024 ns
Block	3	0.092	0.031	3.03	0.0429 *
Manure*Harvesting frequency	6	0.028	0.005	0.46	0.8291 ns
Error	33	0.332			
Total	47	0.790			
R-square= 0.58 CV=15.3 Root MSE=0.100					
Organic matter (%)					
Manure	3	1.055	0.352	11.90	<.0001 ***
Harvesting frequency	2	0.002	0.001	0.03	0.9679 ns
Block	3	0.172	0.057	1.94	0.1423 ns
Manure*Harvesting frequency	6	0.055	0.009	0.31	0.9276 ns
Error	33	0.975			
Total	47	2.258			
R-square= 0.57 CV=15.5 Root MSE=0.170					
Available phosphorus (ppm)					
Manure	3	22445.052	7481.684	34.20	<.0001 ***
Harvesting frequency	2	281.55	140.773	0.64	0.5319 ns
Block	3	2810.83	936.942	4.28	0.0117 *
Manure*Harvesting frequency	6	1405.524	234.254	1.07	0.3997 ns
Error	33	7219.335	218.768		
Total	47	34162.285			
R-square= 0.79 CV=21 Root MSE=14.8					
Total nitrogen (%)					
Manure	3	0.038	0.013	1.07	0.3765 ns
Harvesting frequency	2	0.022	0.011	0.91	0.4126 ns