AVAILABILITY AND UTILIZATION OF INDIGENOUS LEAFY VEGETABLES (ILVs) FOUND IN LIMPOPO PROVINCE AND THE RESPONSE OF A SELECTED ILV TO PLANTING DENSITY AND NITROGEN FERTILIZER RATE

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DECLARATION

I, Mahlogonolo Hunadi Ramaesela Mabala hereby declare that this dissertation submitted for the Masters of Agricultural Management degree at the University of Limpopo is my own work and has not previously been submitted for a degree at this or any other institution and that all the references used or quoted have been indicated and acknowledged.

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DEDICATION

I dedicate this research to my family, my daughter Bokamoso, my son Bokang, my sister Tshepiso and my little brothers Katlego and Ofentse. A special feeling to my loving parents Mr and Mrs Mabala who have supported me throughout the research. I also dedicate this work to everyone who was there for me throughout the entire study period.

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ABSTRACT

A survey study identified indigenous leafy vegetables (ILVs) utilized by rural communities in Limpopo Province in the three districts of Capricorn, Sekhukhune and Vhembe focusing on their availability, agronomic practices, marketing, medicinal and cultural roles, as well as their nutritional value. An ILV that was highly preferred and with good marketing potential was identified for further studies on its response to planting density and nitrogen fertilizer rate.

A questionnaire survey was used to gather information about types of ILVs utilised, their production practices, marketing of ILVs and their importance in medicinal and cultural roles. Data collected were subjected to analysis using the Statistical Package for Social Sciences (SPSS) using descriptive statistics. Results showed that there were 45 different types of ILVs identified from the three districts in Limpopo Province. Farmers indicated that cultivation of these vegetables was mostly done from October to January in Sekhukhune and Capricorn district while in Vhembe it was practiced all year round. Most of farmers in Vhembe district used inorganic fertilizer during planting while farmers in Sekhukhune and Capricorn districts used organic fertilizers such as cattle manure. Irrigation was commonly used in Vhembe district through furrow irrigation system whereas in Capricorn and Sekhukhune districts most farmers relied on rainfall. Farmers indicated that harvesting was done at an early growing stage of the crop. Indigenous leafy vegetables were mostly marketed in local communities. Several ILVs were identified as preferred and regularly consumed as vegetables. Spider plant (*Cleome gynandra*) and nightshade (*Solanum retroflexum)* were identified as the most consumed ILVs in the three districts. Comparing the market potential of the two vegetables, *S. retroflexum* was chosen for further studies on its response to plant density and nitrogen fertilizer rate. The first study investigated the effect of varying plant density (inter and intra-row spacing) and the second study evaluated the response of intra-row spacing and nitrogen fertilizer (LAN-28%N) rate on growth and yield of *S. retroflexum* during 2014 (April to May) and 2015 (March to May) growing seasons.

The plant density experiment was laid out as a 3 x 4 factorial arrangement in a randomised complete block design (RCBD) with three replications. The treatment factors were 3 inter-row spacings of 30, 45 and 60 cm and 4 intra-row spacings of

7.5, 15, 22.5 and 30 cm. The data collected included plant height, plant vigour, number of leaves and branches per plant as well as plant leaf yield. Data were subjected to analysis of variance (ANOVA) using STATISTIX 10.0 package and mean treatments were separated using Turkey HSD at 5% probability level. The results revealed that growth parameters (plant height, plant vigour, number of branches and leaves) and plant leaf yield were significantly influenced by the combined inter and intra-row spacings. Closer inter-row spacings of 30 cm and 45 cm, and intra-row spacings of 7.5 and 15 cm produced the highest values of parameters and plant leaf yield. The combined spacings of 30 x 7.5 cm produced the highest plant leaf yield.

The second study was also laid out as a randomised complete block design (RCBD) with three replications. The treatments were 6 x 2 factorial arrangement: 6 levels of nitrogen (LAN-28%N) at 0, 20, 40, 60, 80 and 100 kg N/ha and two intra-row spacings of 15 and 30cm. Inter-row spacing of 30 cm was used. The nitrogen fertilizer was applied a week after transplanting and repeated a week after first harvesting. Data was subjected to analysis of variance (ANOVA) using STATISTIX 10.0 package. Where significant differences were detected, means were separated using Turkey HSD at 5% propability level. The results suggested that both nitrogen fertilizer and spacing can be used to enhance growth and leaf yield of *S. retroflexum* vegetable. Nitrogen fertilizer rate and plant density significantly ($P \leq 0.05$) affected plant growth and plant leaf yields. Growth parameters and leaf yield were optimised using closer spacing of 15 cm and applying nitrogen at 60 kg N/ha. The application of 60 kg N/ha and 15 cm spacing was therefore recommended for the production of *S. retroflexum* as a vegetable, if planted at 30 cm inter-row spacing.

Key words: Indigenous leafy vegetables, agronomic practices, *Solanum retroflexum*, planting density, nitrogen fertilizer, planting date

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ABBREVIATIONS

AL	Aluminium
ANOVA	Analysis of variance
Ca	Calcium
Cu	Copper
DAFF	Department of Agriculture, Forestry and Fisheries
FAO	Food and Agriculture Organisation
Fe	Iron
HSD	Honest Significant Difference
ILVs	Indigenous leafy vegetables
K	Potassium
Kg N/ha	Kilogram Nitrogen per hectare
LAN	Lime ammonium nitrate
Mg	Magnesium
Mo	Molybdenum
N	Nitrogen
Na	Sodium
P	Phosphorus
SPSS	Statistical Package for Social Sciences
WAT	Weeks after transplanting
Zn	Zinc

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Background information

There is a wide variety of indigenous leafy vegetables (ILVs) found in Africa, which are used for reducing poverty and ensuring food security among rural communities. According to the Food and Agriculture Organization (FAO, 1988) indigenous/ traditional vegetables are all plants whose leaves, fruits or roots are edible and used as vegetables by urban and rural communities through custom, habit and tradition. Gockowski *et al*., (2003) defined indigenous/traditional leafy vegetables as those leafy green vegetables that have been domesticated or originally cultivated in Africa for the last several centuries.

In South Africa, Wehmeyer and Rose (1983) identified more than 100 different species of plants that were being used as leafy vegetables. These crops form part of the daily staple diet of South Africans and are rich in nutrients, e.g. vitamin A and iron. Species such as *Amaranthus spp.*, *Corchorus spp.* and *Cleome spp.* are important sources of food and nutrients. They have high nutritional value and contain significant levels of calcium, iron and vitamins A and *C. Amaranth* and *Corchorus* are also rich in protein and fibre. Most of these ILVs are currently harvested from the wild, while only few are cultivated or are considered as weeds in arable lands. Kordylas (1990) reported that ILVs are mainly consumed when fresh, but can also be preserved using traditional drying methods or a solar method.

Most small-holder farmers in Limpopo Province fall under the resource-poor category characterized by marginal soils that are mainly utilised under rain-fed conditions. Resource-poor agriculture has complex farming systems that are risk prone forcing farmers to diversify their livelihoods. Subsistence farmers use a mixture of traditional and conventional farming practices. Most of these farmers cultivate the indigenous/traditional vegetables for food security, nutrition and cultural purposes.

Indigenous leafy vegetables play an important role in ensuring intake of various essential vitamins and mineral elements, thus avoiding the problem of malnutrition (Yamaguchi, 1983). The FAO (1988) pointed out that the problem of malnutrition is most escalated among children and pregnant women, and is responsible for high mortality rates of these groups. Insufficient consumption of vegetables annually causes 2.7 million deaths worldwide, and is one of the top 10 risk factors contributing to human mortality (Prescott-Allen and Prescott-Allen, 1990).

Most indigenous vegetables tend to have short production cycles, require intensive labour but few purchased inputs, and produce high yields with high nutritional value. Indigenous vegetables are well adapted to harsh climatic conditions and disease infection and insect infestation. They have a short growth period with most of them being ready for harvesting within 3-4 weeks, and respond very well to organic fertilizers. Most of them have an inbuilt ability to withstand and tolerate some biotic and abiotic stresses (Abukutsa-Onyango, 2003). However, most indigenous vegetables tend to be seasonal and hence may require storage to spread their availability.

Some of the indigenous vegetables that are mostly consumed in the Southern Africa include amaranth (*Amaranthus species*), spider plant (*Cleome gynandra*), nightshades (*Solanum species*), cowpeas (*Vigna unguiculata*), African eggplant (*Solanum aethiopicum*), African kale (*Brassica carinata*) and jute mallow (*Corchorus olitorius*). These are the most important indigenous vegetables that are consumed by urban and rural areas dwellers as relish (Jansen Van Rensburg *et al.,* 2007).

Plant density is one of the most important factors in crop production. Plant density, either high or low can affect crop leaf size, plant height, nutrient quality, growth duration and hence lead to poor yield. The optimum plant density depends on different factors which include: plant characteristics, growth duration, planting time and methods, soil fertility, plant size, available moisture, sunshine, planting pattern and weed prevalence (Shirtliffe and Johnston, 2002).

Good soil fertility encourages vigorous growth and increased leaf production (FAO, 1988). Nitrogen, phosphorus and potassium are important plant nutrients that are required by plants in large quantities. These plant nutrients are important for plant growth and can be added into the soil in the form of fertilizers. The amount of fertilizer applied into the soil depends mostly on the type of crop, type of soil and soil nutrient status. Nitrogen has been reported to have a tremendous effect on leaf growth and yields of nightshade (Marshner, 1995; Onyango, 2003) and can also affect growth and yield of leafy vegetables through its effect on cell division and expansion (Abukutsa-Onyango, 2002).

Delayed planting in summer growing season exposes plants to the risk of frost damage before crop maturity at the end of the season. Generally, the time of planting varies depending on the climatic conditions of the area and the type of crop to be grown. The optimal temperature for nightshade varies between 20°C and 30°C, but most Solanum species will also grow within a range of 15°C and 35°C and are sensitive to frost. A day length of 16 hours is ideal for growth (Edmonds and Chweya, 1997). Maximum growth and biomass production was obtained when nightshade species were grown in full sunlight during winter and under shade during summer (Edmonds and Chweya, 1997).

1.2 Problem statement

The extent of ILV use in different parts of South Africa is not fully described and there are no local recommendations for growing *S. retroflexum*. The use of ILVs is declining in all areas of South Africa and the agronomic knowledge of their production is sparse. The decline in the use of these vegetables may be due to lack of knowledge on their nutritional value, their potential for income generation, and medicinal and cultural uses.

1.3 Motivation of the study

Indigenous leafy vegetables play a very important role as a source of nutrients to the human body and their consumption ensures intake of various essential vitamins and mineral elements thus avoiding the problem of malnutrition. Indigenous leafy vegetables adapt well to harsh environments, are easy to grow, require simpler technology and low inputs and have the ability to tolerate pathogens, thus requiring little crop protection (Abukutsa-Onyango, 2003). Therefore, indigenous vegetable crops can play an important role in reducing poverty, enhancing household’s food and nutrition security and rural livelihoods. They also have potential to generate income and improve family nutrition. Some ILVs harvested in the wild are not always available in adequate quantities. Therefore, there is need to document ILV utilization in Limpopo and identify researchable niches that can further enhance their availability and utilization.

1.4 Purpose of the study

1.4.1 Aim

To identify ILVs utilized by rural communities in Limpopo Province and describe their availability, agronomic practices, marketing, medicinal and cultural roles as well as their nutritional value and to identify the mostly preferred ILV that has marketing potential for further agronomic studies.

1.4.2 Objectives

In order to achieve finding from chapter 3 to 5 the following objectives were addressed:

- To identify and determine the ILVs utilized, management practices, nutritional contents, medicinal and cultural roles as well as marketing potential of ILVs found in the three districts of Limpopo province
- To determine the effect of planting density on growth and leaf yield of the selected ILV.
- To determine the effect of nitrogen fertilizer rate and planting density on growth and leaf yield of the selected ILV.

CHAPTER 2

LITERATURE REVIEW

2.1 Description of indigenous leafy vegetables (ILVs)

Indigenous leafy vegetables are plants whose leaves, fruits or roots are acceptable and used as vegetables by rural and urban communities through custom, habit and tradition. Indigenous leafy vegetables are usually not available on commercial scale. However, they have the potential for income generation but fail to compete with exotic varieties due to lack of responsiveness to management. Most of these crops are not cultivated (Lewu and Mavengahama, 2010).

2.2 Potential of ILVs to contribute to food security

Indigenous leafy vegetables contribute to food security and poverty alleviation especially for those people in rural areas. However, their potential to contribute to household food security is contested as some have indicated that since these vegetables are needed only in small quantities as relish as such they cannot play a significant role in food security (Mavengahama, 2013). Yet these vegetables are important for rural households who consume them with porridge as relish. Gomez (1988) emphasized the need for the development and exploitation of wild food resources through improved production practices, storage, preservation and utilization technologies if they are to play a significant role in food security. Indigenous leafy vegetables have been found to play an important part in food security in South Africa, especially as a dried food source during winter (Vorster and Jansen Van Rensburg, 2005). Maundu *et al.,* (1999) and Schippers (2002) pointed out that green or purple fruit from *Solanum eldoretii* are much appreciated and the orange berries of *Solanum villosum* are especially liked by children. In most regions, *Solanum americanum* fruit are believed to be inedible, but in some eastern and southern African areas, ripe and sweet fruit of local varieties are much appreciated (Manoko and Van Der Weerden, 2004). As the leaves are bitter sometimes no salt was used or the leaves are mixed with less bitter vegetables such as amaranth (Maundu *et al.* 1999; Manoko and Van Der Weerden, 2004). However some people, especially elderly people, are fond of a higher degree of bitterness and will prepare flowers and young fruits together with leaves and shoots (Manoko and Van Der Weerden, 2004).

2.3 Consumption and nutritional content of ILVs

The nutrient values of the plants vary with soil fertility, plant age and type (varieties) (Chweya, 1997). Indigenous leafy vegetables play an important role in the African agricultural and nutritional systems. They are used in meals as side dishes, relish and/or for food variety and decoration. These vegetables have high protein and vitamin content and can eliminate nutrient deficiencies amongst children, pregnant women and poor people living in rural areas. Because they are cheaper, ILVs can replace meat in the diets of those who cannot afford to buy meat (Lyatuu and Lebotse, 2010). For example, amaranth leaves are rich in calcium, iron and vitamins A, B and C. Spider plant (*Cleome gynandra*) leaves have a mildly bitter taste but contain 5% protein, 6% carbohydrates and are high in Vitamin A and C, calcium, phosphorus and iron. Cowpea (*Vigna unguiculata*) leaves have high vitamin and protein content, and the plants also fix atmospheric nitrogen in the soil. Nightshades are known to contain adequate amount of essential nutrients that the body needs to be healthy. The leaves can provide sufficient amounts of protein and amino acids, minerals including calcium, iron and phosphorus, vitamins A and C, fat and fibre, as well as appreciable amounts of methionine, an amino acid scarce in other vegetables (Fortuin and Omta, 1980; FAO, 1988).

2.4 Indigenous leafy vegetables commonly consumed in Southern Africa

These vegetables include Amaranth (*Amaranthus spp*), Cowpea leaves (*Vigna spp*), Nightshade (*Solanum spp*), Spider plant (*Cleome spp*), pumpkin leaves (*Cucurbita spp*) and Jute Mallow (*Corchorus spp*).

- Amaranth is known as misbredie, hanekam, varkbossie in Afrikaans, pigweed, cockscomb and hell’s curse in English, unomdlomboyi, imbuya, umifino umtyuthu in isiXhosa, imbuya, isheke, in isiZulu, thepe, theepe in siPedi, Sesotho and Setswana, imbuya in siSwati, vowa, theebe in Tshivenda, theyke, cheke in Xitsonga and mowa in Shona (Fox and Norwood Young, 1982; Bromilow, 1995; Van Wyk and Gericke, 2000, Vorster *et al*., 2002). Cooked amaranth leaves are a good source of vitamin A, vitamin C and folate. They are also a complementing source of other vitamins such as thiamine, niacin and riboflavin, plus dietary minerals including calcium, iron, potassium, zinc, copper and manganese.

- Cowpeas are known as dinawa in isiNdebele; iimbotyi in isiXhosa; imbumba, indumba, isihlumanya in isiZulu; monawa in Sepedi; monawa, dinawa, nawa in Sesotho; dinawa in Setswana; munawa (plant) , nawa (bean) in Tshivenda; dinaba, munaoa, tinyawa in Xitsonga and nyemba in Shona (Fox and Norwood Young, 1982; Bromilow, 1995; Van Wyk and Gericke, 2000; Vorster *et al*., 2002). Cowpea plant is a warm-season crop well adapted to many areas of the humid tropics and temperate zones. Cowpea leaves are rich in potassium with good amount of calcium, magnesium and phosphorus. The leaves also have small amount of iron, sodium, zinc, copper, manganese and selenium. Cowpea leaves are also rich in vitamin A and C. It has good amount of thiamine, riboflavin, niacin, vitamin B6 and pantothenic acid. It also has small amounts of folate and contains around 25% protein and low in fats (Health benefit of cowpea, 2009).

- Spider plants are known as cat whiskers and African cabbage in English; lude, ulude, ulube in isiNdebele; amazonde in isiZulu; lerotho in Sepedi and Sesotho; murudi in Tshivenda; rirhudzu, bangala in Xitsonga and nyevhe in Shona (Fox and Norwood Young, 1982; Bromilow, 1995; Van Wyk and Gericke, 2000, Vorster *et al*., 2002). The spider plant is a fast growing plant that is ready for harvest in short a time of three weeks. The leaves are eaten as a cooked green vegetable, have a mildy bitter taste and contain 5% protein, 6% carbohydrates and are high in vitamins A and C, calcium, phosphorus and iron (Woomer and Imbumi, 2003).

- Jute mallow is known as Jute in English; thelele and lingusha in Sepedi, Sesotho and Setswana; delele in Tshivenda and guxe, ligushe in Xitsonga (Fox and Norwood Young, 1982; Bromilow, 1995; Van Wyk and Gericke, 2000, Vorster *et al*., 2002). It is called derere remusango (“okra’ from the wild) in Shona (Mariga personal communication). The leaves are very nutritious, rich in beta-carotene, iron, protein, calcium, thiamin, riboflavin, niacin, folate, vitamin C and E and dietary fibre (DAFF, 2012).

- Nightshade (English) is known as nastergal, galbessie and nagskade in Afrikaans; ixabaxaba in isiNdebele; umsobo, sheshoabohloko and umsobo-sobo in isiXhosa; umsobo, isihlalakuhe, udoye, umagqa, umgwaba, umsobo-sobo (fruit) and umqunbane in isiZulu; lethotho in isiPedi; seshoa-bohloko, sehloabohloko and momoli in Sesotho; msobo and umsobo in siSwati; muxe in Tshivenda; kophe in Xitsonga; and musaka in Shona (Fox and Norwood Young, 1982; Bromilow, 1995; Van Wyk and Gericke, 2000 and Vorster *et al*., 2002). Nightshade leaves are known to provide an appreciated amount of protein and amino acids, minerals including calcium, iron and phosphorus, vitamin A and C, fats and fibre (FAO, 1988).

2.5 Cultivation and management of ILVs

Farming of these vegetables is mostly done by women farmers rather than by men. Most rural farmers cultivate the ILVs in intercrops with cereal crops such as maize, sorghum and pearl millet. Production of these vegetables is usually low due to various constraints such as lack of knowledge of production, lack of inputs, poor soils, uneven rainfall and requirement in low quantities. The growing period of most of these vegetables is limited to a few months of the year when rains are available (summer) as most are sensitive to cold temperatures and need water to grow (Schippers, 2007). There are some that do not need to be cultivated but grow naturally on their own. These vegetables grow mostly on disturbed soils and do not need any management. Several ILVs, which were originally picked from the wild, have been domesticated and some of their nutritional attributes are well documented. These include spider plant (Woomer and Imbumi, 2003), nightshade and jute mallow (DAFF, 2012). Nightshade is now grown as a commercial irrigated crop by smallholder farmers in Vhembe District of Limpopo Province (Van Averbeke and Juma, 2006). Spider plant and Jute mallow are picked from arable lands where they grow as weeds in cultivated crops and are selectively not weeded in most rural communities of Limpopo province and some parts of Southern Africa. Bunches of fresh spider plant and its dried leaves are also sold in urban markets in Zimbabwe (Mariga- personal communication).

2.6 Harvesting and storage of ILVs

Most of these vegetables are harvested at an early growing stage. The uncultivated ILVs are harvested when they have 5 to 7 true leaves while the cultivated ones are harvested 2 weeks after emergence. During the summer season they can be found in large quantities that can lead them to be preserved for future use in a dried form. In Sub-Saharan Africa, sun drying directly from harvest or after light boiling is the major method of processing leafy vegetables to make them available during periods of scarcity. Whilst drying solves the problem of perishability, it does not satisfy the needs of a large population of consumers, particularly urban dwellers, who prefer freshly harvested vegetables (Smith and Ezyaguirre, 2007).

2.7 Medicinal utilization of ILVs

In addition to consumption, ILVs are also sources of traditional medicine. Adebooye *et al*., (2003) documented traditional medicinal uses of twenty-four ILVs. For example, *Brassica* species have been shown to contain glucosinolates, which are highly effective against cancer and heart diseases. The Spider plant, for example, has been reported to relieve constipation and to facilitate child birth (Heever van den and Venter, 2007), while African nightshade has been documented to cure stomachache (Adesina and Gbile, 1984). People suffering from diseases such as high blood pressure, HIV/AIDS, cancer, and hypertension have been advised to consume ILVs for medical cure (Lyatuu and Lebotse, 2010). For example in Kenya, unripe fruits of *S. villosum* are applied to aching teeth, leaves are used for stomach-ache, an extract from pounded leaves and fruits used to treat tonsillitis, and even roots are boiled in milk and given to children as tonic (Maundu *et al.,* 1999) and it is believed that pregnant women who eat boiled leaves of *S. nigrum* species will ease child-birth by reducing the duration of labour, and will recover rapidly after giving birth (Edmonds and Chweya, 1997). Moreover, pregnant women who eat this vegetable are believed to recuperate well after delivery. It is also believed that children eating the vegetable do not get ‘marasmus’ or ‘kwashiokor’, especially if the vegetable is cooked with milk or groundnuts. Furthermore, in Tanzania, the juice extracted from *S. americanum* leaves is used to treat chronic conjunctivitis (Manoko and Van Der Weerden, 2004). In India, the freshly prepared extracts of *S. nigrum* plants are used to reduce blood pressure and the berries as a tonic, diuretic and cathartic medicine and to cure heart disease. In Japan Saijo *et al.,* (1982) reported that immature fruits of *S. nigrum* contain steroidal glycosides which show considerable anticancer activity. In East Africa the raw fruit is chewed and swallowed for treatment of stomach ulcers that cause continued stomach-ache. Infusions of leaves and seeds are rubbed onto the gums of children who have developed crooked teeth. Lastly, various parts of nightshade plant are believed to cure malaria, black fever, dysentery and urinary infection (Kokwaro, 1976).

2.8 Indigenous leafy vegetables used for income generation

African leafy vegetables (AIVs) are easily available and cheap in village markets, but expensive in undersupplied urban markets, indicating that they have potential to become commercially important and can increase their market value (Schippers, 2000). Nightshade is one of the most important African indigenous vegetables that have considerable potential as cash income earners, enabling the poorest people in the rural communities to earn a living (Schippers, 2000, Onyango, 2003). They provide employment opportunities and generate income for the rural population. Recent studies in Western Kenya revealed increased use of AIVs and decreased use of exotics (cabbage, kale, spinach), mainly because AIVs are low input (cheaper to produce) compared to exotics and consequently more affordable for many rural households in the low-income bracket. For example, Adebooye and Opabode (2004) reported that *Solanecio biafrae* an ILV in southwest Nigeria is several times more expensive than the routinely cultivated species, especially during the dry season. Due to high demand for these leafy vegetables, most small scale farmers have invested in their production with success (Lyatuu and Lebotse, 2010). In some irrigation schemes in South Africa, pumpkin leaves are traded commercially and even sold in urban supermarkets.

2.9 Marketing ILVs

Recently, there has been an increase in the consumption of some ILVs, which has raised their demand on the markets. However, the supply of ILVs for the markets has not been exploited due to lack of knowledge on marketing of ILVs. It has been reported that there is a risk of losing ILVs in Tanzania, Zambia and Botswana due to farmers replacing them with improved/exotic varieties; lack of seed and information about their performance; input requirements and marketing (Lyatuu and Lebotse, 2010). In South Africa, many ILVs are obtained by collecting in the wild and not by means of cultivation. The major constraints of production include lack of good quality seed and lack of practical information on their production, as well as poor efforts to promote them.

2.10 Effect of planting date on growth and yield of vegetables

Choosing an appropriate sowing date for a crop is one of the most important factors in its production when it is cultivated. Appropriate sowing date of a crop is a date when the plants can be well established and their susceptible growth stages do not coincide with adverse environmental conditions (Seghatoleslami *et al*., 2013). Planting date is one of the important aspects in crop production and is significantly influenced by different plant crop varieties and temperatures of different locations. Optimum planting time ensures proper crop growth and development resulting in maximum yield and quality. Proper manipulations of planting date make it possible for the crops to escape peak period of weed infestation, competition and damage caused by environmental factors (Thompson and Kelly, 1957). Mokwele (2009) reported that nightshade is grown throughout the year in Vhembe but the majority of farmers plant it in February/March (33%) and June/July (34%) periods. Ramugumo (personal communication) also indicated that in Vhembe, nightshade is planted from March until November.

2.11 Response of vegetable yield to plant spacing

Plant spacing is one of the most important measures in crop production. Plant spacing plays a significant role on crop performance and has been seen as a critical aspect in optimizing crop growth and yield. Optimum plant spacing ensures proper growth and development of plants resulting in maximum yield of the crop. Edmonds and Chweya (1997) reported that a total yield of 5 t/ha per season was obtained after six sequential harvests when plants were transplanted at a spacing of 60 x 10 cm. Fortuin and Omta (1980) calculated that a leaf yield of at least 15-20 t/ha could be expected if the *S. nigrum* plants were spaced at 30 x 30 cm intervals and the whole plant uprooted after 1 month growth. Mokwele (2009) reported that farmers at Tshiombo irrigation scheme in Vhembe reported that they planted *S. retroflexum* in rows 40 to 60 cm apart and use intra-row spacing of 15-25 cm. Some farmers in Vhembe, plant at a very high density in 30 cm rows at 5-7.5 cm spacing between plants (Ramugumo, personal communication). The Department of Agriculture, Fisheries and Forestry (DAFF) recommends a plant spacing of 30 cm x 30 cm for nightshade (*S. retroflexum*) (DAFF, 2013). The Food and Agricultural Organization recommends inter-row spacing of 30-60 cm and intra-row spacing of 15-50 cm (FAO, 1988), recognising the diversity in growth habits in the genus Solanum. For seed production, a spacing of 75-120 cm between plants should be used (Epenhuijsen, 1974). Fisher (1977) reported a spacing of 1 m between both plants and rows to provide optimal growth conditions for plants conspecific with *S. scabrum* in North America. There are wide variations of planting density for nightshade both locally and internationally, this is due to differences in morphological features of nightshade species.

2.12 Effect of fertilizer on growth and yield of Solanum vegetables

Fertilizer is any organic or inorganic material of natural or synthetic origin that is added to a soil to supply one or more plant nutrients essential for the growth of plants (Murwira and Kirchmann, 1993). It is important to determine the soil nutrient status before applying fertilizers; this will help in applying the optimum fertilizer in order to obtain the targeted crop yield. Nutrient supply practices varied widely among farmers, both in terms of choice of fertilizers and the rates at which these were applied (Van Averbeke and Khosa, 2004). Nitrogen, phosphorus and potassium are known to be the most important plant nutrients that plants require in fairly large amounts to develop and grow well. These nutrients are known to improve growth and yield of vegetable crops. Solanaceae require fairly large amounts of nitrogen and other nutrients for optimum growth and do well in soils that are rich in organic matter (Schippers, 2000). Merinyo (1996) investigated the effect of manure and nitrogenous fertilizers on the yield and harvest duration of black nightshade. The study showed that rate of application of both nitrogen fertilizer and farm yard manure had an influence on the total leaf yield of *S. nigrum*. The application of 150 kg N/ha and 10 t/ha cattle manure produced the highest leaf and shoot yield of the crop. Chweya (1997) also conducted a study on the effect of nitrogen fertilizer on leaf yield and nutritive quality of *S. nigrum*. The plants were supplied with nitrogen at four different rates, namely 0, 5, 10 and 15 g N/ plant. The study showed that *S. nigrum* responded well to N applications with an application of 5 g N/ plant, which equals to 200 kg N/ha, giving optimum growth and yield. Fertilizers are very important in the growth and development of plants and therefore need to be considered when starting to grow crops.

2.13 Response of growth and yield of crops to spacing and fertilizer

Soil fertility and plant spacing are important aspects for production of different crops. Optimum fertilizer rates and plant spacing ensure proper growth and development of plants resulting in maximum yield. Dimri and Gulshan (1997) working on the nitrogen levels of 0, 60, 90 or 120 kg/ha and spacing of 60cm x 60cm, 60cm x 45cm, 60cm x 30cm and 30cm x 30cm, reported that increasing rates of nitrogen fertilizer and plant spacing in tomato resulted in increased N and chlorophyll content in leaves at all three growing stages of the plant (pre-flowering, flowering and fruit ripening stages). Studying the yield of okra as affected by spacing and nitrogen levels, Birbal *et al.,* (1995) working with spacing of 30cm x 30cm, 45cm x 30cm, 45cm x 45cm, 60cm x 20cm or 60cm x 30cm with nitrogen applied at 50, 100 and 150 kg/ha, observed that the tallest plants (109.2cm) were obtained with closer spacing 30cm x 30cm and highest nitrogen application at 100 and 150 kg/ha. The number of branches per plant was also highest at 45cm x 45cm and 100 and 150 kg N/ha than at 0 and 50 kg N/ha and also number of fruits per plant, individual fruit weight and yield per plant were highest with 45cm x 45cm and 60cm x 30cm compared to the control.

CHAPTER 3

SURVEY STUDY

3.1 Introduction

A questionnaire survey was used to collect data on the utilization, production practices and marketing of ILVs, as well as their medicinal and cultural uses. The mostly preferred ILVs were identified and, where possible, some collected for nutrient analysis.

3.2 Materials and methods

3.2.1 The survey

The survey study was conducted in selected three districts of Limpopo province namely: Capricorn, Sekhukhune and Vhembe in South Africa during May to July 2013. The data gathered were subjected to descriptive statistical analysis using the Statistical Package for Social Sciences (IBM SPSS, 2010) version 17.0.

Key informant interviews were conducted using a reconnaissance survey method prior to the formulation of the survey questionnaire in order to guide with the development of the main questionnaire that was utilized to interview farmers and communities. A number of 135 respondents were interviewed from each district giving a total of 405 respondents. Small-holder farmers and those who have backyard gardens were selected in each area and interviewed per household during the survey.

3.2.2 The research districts

In Capricorn district, the study was conducted in Polokwane municipality in Segopje, Ga-Molepo and Mamotintana villages. The respondents were randomly selected and interviewed in the three villages. The municipality has 65 829 households and 0.2% of the households were interviewed.

In Sekhukhune district, the study was conducted in Makhuduthamaga municipality in Clencowie village. Small-scale farmers working under different farming projects were randomly selected and interviewed. The municipality has 178 001 households and only 0.08% of the households constituted the survey sample.

In Vhembe district, the study was done in Thulamela municipality in three irrigation schemes namely Khumbe (23°03'S; 30°21'E), Dzindi (23°01'S; 30°26'E) and Tshiombo (22°48'S; 30°30'30"E). Farmers working in these irrigation schemes were randomly selected and interviewed. The municipality has 156 594 households and only 0.09% were interviewed per household.

3.2.3 Nutritional analysis

After the survey, the leaves of the mostly preferred ILVs from the three districts were collected and sent for mineral nutrient analysis at Feed Laboratory Department of Agriculture and Environmental Affairs, KwaZulu-Natal Province, South Africa. The leaf samples were washed with tap water and boiled in stainless steel pot before being analysed. Analysis of minerals (P, Ca, Mg, K, Na, Cu, Zn, Mn, Fe, and Al) in the plant material was conducted using Hunter's dry matter method (Hunter, 1984). Samples of 0.5g of plant material were measured into 100 ml beakers. This was dried in an oven for two hours and then reweighed before being ashed overnight in a furnace at 450°C. The ashed contents were then digested with 2 ml of concentrated hydrochloric acid (HCl) and evaporated slowly to dryness on a water bath in the fume cupboard with the extractor fan on. Then 25 ml of 1M HCl was added and the solution was stirred using a rubber policeman before it was filtered through Advantec 5B:90 mm diameter filter paper into a sample cups. The filtrate was diluted with de-ionized water, ratio 5:20. The diluted solution was analysed for elements on ICP-OES. The setting standards also went through the same dilution as the samples.

3.3 Results and discussion

3.3.1 Characteristics of respondents

During the survey, the data on gender, age, occupation, number in a family and the period they stayed in that area\village were collected.

(a) Gender

From the gender profile, more women (93.5%) were chosen to participated during the survey than men (Table 3.1), this is because men do not know much about the production of indigenous vegetables. Women are the ones who mostly do the planting, harvesting and cooking of these vegetables in many households, this give us a confident that they know much about indigenous vegetables. ICRA (2002) stated that women and men share most of the farm activities; and that women are traditionally responsible for procurement of seeds and other inputs, and are key players in production, harvesting and transporting of vegetables to the market, processing and preservation, while men usually till the land. Schippers (2000) supported this notion and indicated that women are the key players in retailing of ILVs and that 94.9% of the retailers were females and only 5.1% were men in Sub-Saharan Africa.

(b) Age

Most of the farmers (347) interviewed in the survey were older people from the age of 41 and above (Table 3.1). Most of these farmers (329) were the heads of the families; they are the ones who are responsible for everything related to food preparation in their family as well as deciding what to eat in their family and are believed to know most of the ILVs found in their villages\areas. In Capricorn and Vhembe District, 41.6% and 31% of farmers respectively, were over 61 years while in Sekhukhune District 70% of the farmers were of the age ranging from 41 to 50 years.

TABLE 3.1: The distribution of respondents by gender and age

DISTRICTS	CAPRICORN (N=135)	SEKHUKHUNE (N=135)	VHEMBE (N=135)
GENDER	Percentage (%)	Percentage (%)	Percentage (%)
Males	8.3	2	28.6
Females	91.7	98	71.4
AGE	Percentage (%)	Percentage (%)	Percentage (%)
20 -30 years	10.4	4	7.1
31- 40 years	0	14	11.9
41-50 years	29.2	70	21.4
51-60 years	18.8	4	28.6
61 years +	41.6	8	31

(c) Household income

Figure 3.1 shows the source of income for each household. Results showed that self-employment was one of the most important sources of income (73 respondents) in Sekhukhune and Vhembe districts while in Capricorn results showed that over 40% of the respondents are unemployed. Crop farming (over 30%) was also shown to be the second most important source of income in Sekhukhune and Vhembe districts while livestock farming only was not practiced in all the three districts. This indicates that livestock farming is no longer considered as an important practice in the study areas.

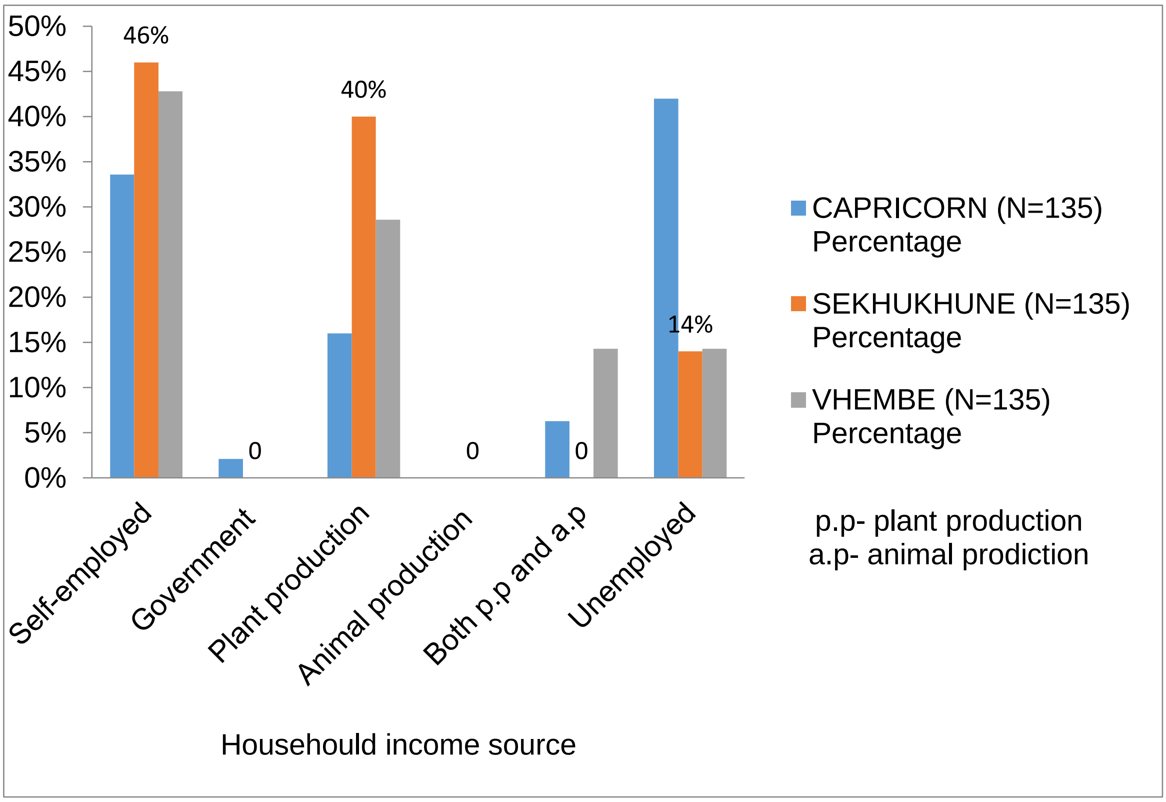


Figure 3.1: The sources of household income in the three districts

(d) Duration of stay in residential area

The results from the survey showed that most of the respondents have resided in their area for more than 20 years (107 for Capricorn, 86 for Sekhukhune and 119 for Vhembe District) (Table 3.2). This might raise confidence that they have more knowledge about ILVs found in their areas, their production practices and their importance in terms of uses, medicinal and cultural roles.

TABLE 3.2: The distribution of farmers according the period of stay in their area

DISTRICTS	CAPRICORN (N=135)	SEKHUKHUNE (N=135)	VHEMBE (N=135)
PERIOD STAYED	Percentage (%)	Percentage (%)	Percentage (%)
5 -9 years	8.3	6	4.8
10 – 14 years	2.1	14	2.4
15 – 19 years	10.4	16	4.8
20 – 24 years	12.5	52	4.8
25 years & above	66.7	12	83.3

3.3.2 Indigenous leafy vegetables utilized in selected districts

Determining ILVs in the three districts helped in identifying the types of ILVs they utilize, their importance as a source of food, medicinal and cultural use as well as their level of availability. There are 45 different types of ILVs identified from the three districts of the Limpopo Province. The collected ILVs were identified at the University of Limpopo Herbarium and at South African Biodiversity Institute (SANBI) Pretoria. Some of the vegetables are not scientifically identified as they are found in a short period of time and people do not consider them as important. The utilization of these ILVs differs according to area, this may be due to the respondents way of living and also their culture. List of cultivated ILVs found in the three districts are shown in Table 3.3 and those collected from the wild are shown in Table 3.4 together with their local names. They are mostly used as a relish, while others could also be used for medicinal or cultural purposes.

Some of the identified ILVs are commonly utilized in all the three districts such as amaranth, cowpea, blackjack, spider plant, jute mallow and pumpkin. Vorster (2007) on the role and production of traditional leafy vegetables in three rural communities in South Africa, reported that amaranth, blackjack, cowpea and pumpkin were consumed in Arthurstone (Mpumalanga Province), Mars\Glenroy (Limpopo Province) and Watershed (Kwa-Zulu Natal). These leafy vegetables are mostly utilized as staple vegetables, because they can be easily found, their production practices do not need much labour and inputs, and can be stored for a longer period for future use. There are some ILVs that are utilized in certain districts whilst not found in others. Nightshade and okra vegetables are utilized in Vhembe district only while wild melon is only found in Capricorn and Sekhukhune districts. These maybe due to climatic conditions experienced in certain areas that do not favour the production of certain vegetables.

TABLE 3.3: Cultivated ILVs and their local names in each of the three districts

COMMON NAMES	SCIENTIFIC NAMES	FAMILY	CAPRICORN DISTRICT	SEKHUKHUNE DISTRICT	VHEMBE DISTRICT
			LOCAL NAMES		
Amaranth	*Amaranthus spp.*	Amaranthaceae	-	Theepe	Vowa
Bitter gourd	*Momordica balsamia*	Cucurbitaceae	Mokgadiasega\ kgobabe	Nkaka	-
Black jack	*Bidens pilosa*	Asteraceae	Moshitji	-	Mushidszhi
Blumea viscosa	*Pseudoconyza viscosa*	Asteraceae	-	Lekgakga	-
Cowpea	*Vigna unguiculata*	Fabaceae	Monawa	Monawa	Munawa
Jute mallow	*Corchorus tridens L.*	Tiliaceae	-	Thelele	Delele
Tsamma	*Citrullus lanatus*	Cucurbitaceae	Motshatsha\ Mogapu	Motshatsha	Mutshatsha
Narrow-leaved vernonia	*Vernonia fastigiata*	Asteraceae	-	Lehlanye	-
Nightshade	*Solanum retroflexum*	Solanaceae	-	-	Muxe
Okra	*Abelmoschus esculentus*	Malvaceae	-	-	Delelemandande
Pumpkin	*Curcurbita spp.*	Cucurbitaceae	Mopotse	Mpodi	Thanga (Phuri)
Small red pepper	*Capsicum annuum*	Solanaceae	-	Pherefere	-
Spider plant	*Cleome gynandra*	Asparagaceae	Leroto	Leroto	Murudi
Tinderwood	*Cleredendrum glabrum*	Capparaceae	Mohloohloo	-	-

Wild cucumis	*Cucumis africanus*	Cucurbitaceae	Monyaku	Monyaku	-
Wild melon	*Lagenaria siceraria*	Cucurbitaceae	Maraka	Moraka	-

Table 3.4 present ILVs that grow naturally from the wild but the community tend to cultivate some of them. There are some of the ILVs not listed in Table 3.4 but are utilized in the three districts. In Capricorn District they include: semetseng (unidentified), sethoku (unidentified), mokopoko (unidentified), lekgokgosha (unidentified), morika (unidentified) and letlowane (unidentified); in Sekhukhune District include: mokgweti (unidentified), molebedu (unidentified), mmoo (unidentified), khuseng (unidentified) and kgelekgetla (unidentified), and in Vhembe District include: lubikela (unidentified). The high number of unidentified ILVs was due to unavailability of them during the survey. Some of these vegetables were used long ago by elder and are rare to found recently, however shortage availability made it possible for them to be replaced by exotic vegetables. There is need for follow-ups to collect samples of these ILVs for further identification and nutritional analysis.

Indigenous leafy vegetables listed in Table 3.4 can also grow where soil is disturbed. In cultivated areas, these vegetables are known to grow as intercrops between planted vegetables or cereal crops such as maize, sorghum and pearl millet. Study conducted by Wehmeyer, (1966) indicated that wild plant species were found to have a higher nutritional value than cultivated genotypes. Vitamin A, iron, calcium and protein have been found in all species of wild vegetables in Africa (Weber and Van Staden, 1997).

TABLE 3.4: Naturally growing ILVs utilized in the three districts of Limpopo province

COMMON NAMES	SCIENTIFIC NAMES	FAMILY	CAPRICORN DISTRICT	SEKHUKHUNE DISTRICT	VHEMBE DISTRICT
			LOCAL NAMES		
Amaranth	*Amaranthus hybridus*	Amaranthaceae	Thepe	Theepe	Vowa
African heartvine	*Pentarrhinum inspidum* E.	Asclepiadaceae	Mofotontsoane	-	Phulule
Black jack	*Bidens pilosa*	Asteraceae	Moshitji	Mokolonyane	Mushidzi
Bitter gourd	*Momordica balsamia*	Cucurbitaceae	Mokgadiasega /Sebabi	Nkaka\ lebabi\ Mogoti\ Lekgakga\ Mosegasegane	Tshibavhe (nngu)
Common sow thistle	*Sonchus oleraceus* L.	Asteraceae	Mantlalekgeru	-	Shashe
Cudweed	*Pseudognaphalium Undulatum*	Compositae	-	Mankoko	-
Datura	*Datura stramonium* L	Solanaceae	-	-	Zavha-Zavha
Devil’s thorn	*Dicerocaryum zanguebaricum*	Pedaliaceae	Tshehlo	Tshehlo	Museto
Elephant’s ear	*Colocasia esculenta*	Araceae	-	-	Mufhongwe
Goosefoot	Chenopodium album	Amaranthaceae	-	Seruwe	Tshiruwe\ Daledale
Jute mallow	*Corchorus tridens* L.	Tiliaceae	Thelele	Thelele	-
Marshmallow	*Malva parviflora* L.	-	Mowatje	-	Tshiteaduvha

Narrow-leaved vernonia	*Vernonia fastigita*	Myrtaceae	Lehlanye	Lehlanye	Muthange
Nettle-leaved goosefoot	*Chenopodium murale*	Amaranthaceae	Mogole	-	-
Nightshade	*Solanum retroflexum*	Solanaceae	Mofye	Lefse\ Lethotho	-
Pigeon wood	*Trema orientalis*	Ulmaceae	-	-	Mukurukuru
Rattle pods	*Crotalaria juncea* L	Fabaceae	Fore	-	-
Soap nettle	*Pouzolzia mixta*	Urtricaceae	Motlatswa		Muthanzwaa
Spider plant	*Cleome gynandra*	Asparagaceae	Leroto	-	Murudi
Spindle pot	*Cleome monophylla* L	Capparaceae	Sethogothogo	Sekalerotwana	Motohotoho
Stinging nettle	*Laportea peduncularis*	Urticaceae	-	-	Dzaluma
Wandering jew	*Commelina benghalensis*	Commelinaceae	-	-	Damba
Wild cucumis	*Cucumis africanus*	Cucurbitaceae	Monyaku	Monyaku	Tshinyaku
Wild granadilla	*Adenia digitata*	Passifloraceae	-	-	Dundu
Wild petunia	*Ipomoea obscura* L.	Convolvulaceae	-	-	Muduhwi

3.3.3 Medicinal and cultural uses of ILVs identified during the survey

Indigenous leafy vegetables are known to have high nutrient contents compared to exotic vegetables. Their high nutrient content enables them to possibly control, treat or prevent some diseases. Most of the medical practitioners encourage people to consume these ILVs in their daily diets in order to keep their bodies healthy. Such practices had been noted in earlier studies of Fox and Norwood-Young (1982) where some of the plants were singled out for pregnant women, the ill and those who need to build their strength. Most of such vegetables have been reported to have medicinal properties (Kokwaro, 1993, Olembo *et al.,* 1995) for instance spider plant has been reported to aid constipation and facilitate birth while African nightshade has been reported to cure stomach ache. Research at the University of KwaZulu-Natal has indicated that *Amaranthus hybridus, Amaranthus dubius, Asystasia gangetica, Galinsoga parviflora, Oxygonum sinuatum, Physalis viscosa* and *Tulbahgia violacea* may be of use in treating hypertension (Mackraj, 2007). The use of these vegetables was part of cultural heritage, playing a significant role in customs and traditions and in maintaining equity within the family structure since the appearance on the family table depends largely on the activities of women (Mnzava, 1997).

<u>Capricorn district</u>

Bittergourd (*Momordica balsamina*) and narrow-leaved vernonia (*Vernonia fastigiata*) are known to lower high blood pressure. Their leaves are boiled and then the resultant supernatant is drunk. Spider plant leaves can also lower high blood pressure; the leaves are half cooked without salt and eaten as relish.

Tsamma (*Citrillus lanatus*) is used to search for ancestors. The dry leaves of tsamma are burned and the person who is looking for his/her ancestors inhales the smoke.

<u>Sekhukhune district</u>

There are number of ILVs that are used for medicinal purpose. For example narrow-leaved vernonia is known to help with high blood pressure as highlighted by the respondents in Capricorn district using the same procedure mentioned above. Narrow-leaved vernonia is also known to help with womb problem, the vegetables roots are boiled and the person with such a problem is advised to drink the supernatant. Spider plant is known to cure ear infection, the roots of the spider plant are crushed and boiled then the resultant supernatant is poured into the infected ear. Wild cucumis (*Cucumis africanus*) helps with diabetes; the vegetable is cooked and eaten as relish.

For cultural use, jute mallow helps with giving birth difficulties. The woman who is about to give birth is advised to eat the vegetable because of its slippery nature it smoothens the baby's delivery. The pumpkin vegetable is used to search for ancestors like tsamma in Capricorn district using the same procedure.

Vhembe district

Nightshade *(Solanum retroflexum)* is known to cure ear infection. The vegetables are boiled and the resultant supernatant is poured inside the infected ear. Bittergourd is used to control high blood as in Sekhukhune and Capricorn district. This practice was also reported in the Limpopo Province in Shangaan villages (Hart and Vorster, 2006). Black jack (*Biden pilosa*) is known to cure wounds; water from the raw leaves is placed on the wound.

3.3.4 Cultivation practices of ILVs in the three districts

Cultivation practices of ILVs differ according to districts. The practices used in Capricorn and Sekhukhune districts were more similar but rather different from Vhembe district.

(a) Planting dates

Planting was done as soon as the normal rainfall starts, from October until January in Sekhukhune and Capricorn districts, but in Vhembe planting was done throughout the year (Table 3.5). Most of the farmers in Sekhukhune and Capricorn practice mixed farming whereby they plant ILVs with the cereal crops such as maize, sorghum and pearl millet. They also indicated that they do not plant from the month of February till May, this simply implies that they depend mostly on rain for their production. But in Vhembe district planting was done from August to May, this may be because most of the participants produce for commercial purposes and because of warm temperatures they experience in the north. Planting was not done in months of June and July and this may be because at that time they have low soil temperatures that would delay or inhibit germination.

(b) Land preparation

There are three main methods that are commonly used to prepare the land for planting namely tractor, donkey and hand hoes (Table 3.5). A high usage of tractor (76.3%) was reported in Vhembe district. The use of donkeys (2.6%) for land preparation was still being practiced but on a limited scale and planting using hand hoe (21.1%) was practiced but with few participants as it took time and effort. The use of the hand hoeing method was mostly preferred in Sekhukhune and Capricorn districts. This may be because they produce these ILVs for consumption, subsistence and informal markets. The tractor cultivation method was used in Sekhukhune (10%) and Capricorn (30.4%) and also the use of animal traction still exists in Capricorn (19.6%) but has stopped in Sekhukhune district. The use of animal traction is no longer preferred by most farmers, and similar results were reported in the study by Vorster (2007) where use of tractor (89%) for seed preparation in Mars\Glenroy was reported. Animal traction teams still exist and are hired in Mars\Glenroy and Arthurstone, but the knowledge associated with animal traction has been lost in Watershed.

TABLE 3.5: Time of planting ILVS and methods used for land preparation

DISTRICTS	VHEMBE (N=135)	SEKHUKHUNE (N=135)	CAPRICORN (N=135)
PLANTING TIME	Percentage (%)	Percentage (%)	Percentage (%)
Aug- Sep	13.2	8	15.2
Oct- Nov	18.4	76	67.4
Dec- Jan	23.7	16	17.4
Feb- Mar	13.2	0	0
Apr- May	31.50	0	0
METHOD OF LAND PREPARATION	Percentage (%)	Percentage (%)	Percentage (%)
Tractors	76.3	10	30.4
Donkeys	2.6	0	19.6
Hand hoes	21.1	84	50

Others	0	6	0

(c) Irrigation

Irrigation is an important component in agricultural production. Plants need adequate supply of water to produce high yield. The types of irrigation used in the three districts are shown in Figure 3.2. Most of the farmers in Vhembe district use furrow irrigation (78.9%) and sprinkler irrigation. The use of these irrigation facilities raises the production cost thus increasing the market price. In Capricorn (73.4%) and Sekhukhune (51%) districts, farmer's production relies on rainfall, thus leading to produce scarcity during dry season. The use of water pipes (2.6%) in Vhembe district is limited because most of farmers produce on big plots, which will need more time and management to irrigate with pipes. Pipe irrigation also requires some pressure. Few farmers in Sekhukhune (6%) and Capricorn (15.7%) use water pipes which make them to spend more of time irrigating.

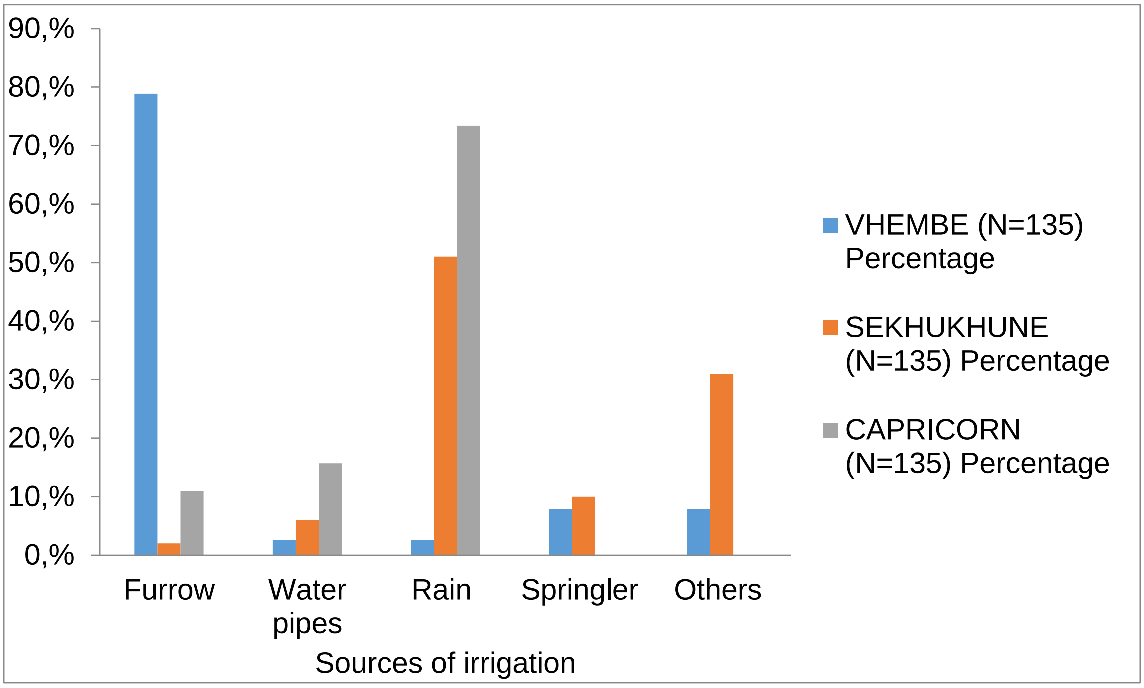


Figure 3.2: Methods of irrigation used in ILVs production

(d) Fertilization

Animals manure and inorganic fertilizers are the main types of fertilizer used in the three districts. Most of the farmers in Vhembe (78.9%) use inorganic fertilizer, the use of this inorganic fertilizer raises the production cost and thus increases the market prices. The majority (98%) used chemical fertilizers, consisting of super-phosphate (10.5 % P), limestone ammonium nitrate (LAN - 28 % N), urea (46 % N) or the fertilizer mixtures 2:3:4 (30) and 2:3:2 (22) (Juma, 2006). Few farmers use inorganic fertilizer in Sekhukhune (2%) and Capricorn (8.7%). The reason for low application of inorganic fertilizer is that it could increase the cost of production. Inorganic fertilizers are expensive for small-holder farmers who often utilize ILVs. McClintock and El-Tahir (2004) also observed that chemical fertilizers are rarely applied in tropical Africa, as they are too costly under uncertain climatic conditions. The use of organic fertilizer in a form of cattle manure was used mostly in Sekhukhune (57%) and Capricorn (37%) but not used in Vhembe district. The use of chicken manure and the combination of cattle and chicken manure was used but practiced by few farmers in the three districts. Juma (2006) reported that about one-third of respondents (36%) applied organic fertilizers consisting of cattle, pig or poultry manure in three irrigation schemes (Dzindi, Rabali and Khumbe) in Vhembe district. Some of the farmers did not apply any of these fertilizers because they believe that the soil could support the growth of the plants without fertilizer. The time of applying fertilizer varied among the districts (Table 3.6). This might be affected by the type of ILVs they grow. Majority of farmers in Vhembe district (31.6%) apply fertilizer during and after planting, these fertilizers are applied in the form of spreading it then irrigate immediately after. In Sekhukhune (59%) and Capricorn (54.3%) of the respondents applied fertilizer before planting. The fertilizer was applied 2 – 4 weeks before planting in a form of spreading then incorporated into the soil. Only few farmers apply fertilizer during planting.

TABLE 3.6: Types of fertilizer used and their application time

DISTRICTS	VHEMBE (N=135)	SEKHUKHUNE (N=135)	CAPRICORN (N=135)
TYPES OF FERTILIZERS	Percentage (%)	Percentage (%)	Percentage (%)
Chicken manure	5.3	2	19.6
Cattle manure	-	57	37
Chicken & cattle manure	2.6	8	8.7
Inorganic fertilizer	78.9	2	8.7

No fertilizer	13.2	31	26.1
FERTILIZER APPLICATION	Percentage (%)	Percentage (%)	Percentage (%)
Before planting	13.2	59	54.3
At planting	5.3	2	19.6
After planting	13.2	-	-
Before and at planting	5.3	-	-
Before and after planting	18.4	8	-
At and after planting	31.6	-	-
No application	13.2	31	26.1

(e) Pest and disease control in the three districts

Results show that 12 farmers in Capricorn district used chemicals to manage insect pests and diseases. Pests are controlled using malathion (active ingredient malathion 81.27% and inert ingredient 18.73%) and blue death (active ingredient Permethrin (Pyrethroid) 3 g/kg) Carbaryl (Carbamate) 15 g/kg, whereby malathion was mixed with water according to its instruction on the label and 100g blue death was mixed in 10 liters of water, then sprayed on the crops while still at the seedlings stage. Similar observations were reported by Vorster (2007) that Arthurtone producers used limited chemicals for pest (19.7%) and disease (18.4%) control, where pest control tends to be in a form of cutworm bait or blue death, a general pesticide, with few using other agro-chemicals.

In Vhembe district farmers used cypermethrin (Pyrethroid) g/l, blue death (Permethrin (Pyrethroid) 3 g/kg, Carbaryl (Carbamate) 15 g/kh) and malathion with active ingredient malathion 81.27% and inert ingredient 18.73% to control problem pests on crops. Dithane M-45 and copper count (Copper as metallic 8.0% and Inert ingredient 92.0%) were used to manage diseases. These chemicals were used when the pest or diseases are visible. Malathion was used to control locusts on nightshade vegetables and blue death for cutworms. Juma, (2006) reported that malathion was the chemical that was used to control insect pests on *S. retroflexum* while dithane M-45 fungicide is used to manage fungal diseases.

In Sekhukhune district only insect pests were controlled using some chemicals. Cutworms were the main problem pests which were controlled using blue death (active ingredient Permethrin (Pyrethroid) 3 g/kg), Carbaryl (Carbamate) 15 g/kg in combination with tobacco, snuff, dish wash liquid and Jeyes fluid. These chemicals were mixed together and sprayed on the crops. The other concoction used was the combination of chili pepper and chopped onion soaked together in water for 5 days then the resultant supernatant was sprayed on crops. No chemicals were used to control plant diseases.

(f) Harvesting and storage of ILVs

Harvesting of ILVs was reported to be done on both cultivated and uncultivated areas in the three districts. The harvesting frequency depends mostly on the crop vigour to regenerate growth. Harvesting practices were similar in the three districts, whereby harvesting was done from an early stage and only fresh leaves were harvested. The ILV leaves are harvested at different stages during the growing cycle. Most people prefer to harvest them from an early stage, since at that stage they are more palatable than at the late stage. Whitbread (1986) reported that there is limited gathering of matured traditional leafy vegetable plants as they tend to have tough, fibrous leaves that made them less palatable. Indigenous leafy vegetables that are found from the wild are harvested at the seedling stage usually when the plants have 3 to 5 true leaves and those that are cultivated are harvested two weeks after germination and re-harvesting is done every 5 to 7 days (cutting the first 3- 5 leaves) until they start flowering and then harvesting stops. Vorster (2007) reported that uncultivated plants are harvested when still young and succulent (seedling stage) but as the plants approach maturity, only the apical rosette of leaves of the stems and branches are harvested. Harvesting of the whole plant of wild ILVs usually occur when these vegetables are seen as weeds (growing where they are not wanted).

Nightshade is an important indigenous vegetable found in Vhembe district only; this vegetable is harvested in a form of cutting the whole shoot 4 to 5 weeks after transplanting and left to re-grow. Continuous harvesting occurs at 4 week intervals until the plant start to develop flowers and narrow leaves. Modi *et al.,* (2006) reported that TLVs are more available and occur in greater variety on cultivated fields than uncultivated areas. Most ILVs preferred are found in a short period of time in the field, therefore some are stored and consumed during off season.

Most ILVs are known to be seasonal and perishable. Drying and storage of TLVs are important aspects that demonstrate the role of indigenous knowledge in the food security strategies of many rural households (Voster, 2007). Storage of ILVs for winter season was reported in the three districts to ensure the access to ILVs in the winter season. There are two main methods identified during the survey that are used to store these vegetables. These methods include fresh leaves dried either under the shade or in sunlight, and cooked leaves dried under the sunlight. Both these methods transform the leafy vegetables into dry products that have long shelf lives (Vorster and Jansen Van Rensburg, 2005). In the three districts, it was shown that cowpea, amaranth, black jack and spider plant are stored as cooked dried leaves while jute mallow and pumpkin are stored as dried fresh leaves. Tsamma (melon) is stored as dried leaves and narrow-leaved vernonia is stored as cooked dried leaves in Capricorn and Sekhukhune districts only. There are some that are not dried and stored but can be found throughout the year, for example; rattle pods and blumea viscosa are found in Capricorn and Sekhukhune districts and also nightshade which is found in Vhembe district but under irrigation system. There are some that are not dried and stored; they are only used when they are available in the field and are uncultivated for example devil’s thorn, letlowane (unidentified), small red pepper and maranca. These findings agree with other studies on storage practices. Study conducted by Nguni and Mwild (2006) indicated that storage of TLVs for winter was practiced in the Transkei and provided the bulk of the food intake in winter. *Corchorus* spp., amaranth, cowpea, cleome and pumpkin were reported being cooked and dried in various villages in South Africa (Hart and Vorster, 2006).

3.3.5 Nutritional content of the mostly preferred ILVs in the three districts

Indigenous leafy vegetables are known to have high nutritional value as compared to exotic vegetables. The nutrient content of these vegetables could be affected by several other factors such as soil type and fertility, stage of growth, storage and cooking. The results of nutritional analysis of selected ILVs are shown in Table 3.7. These vegetables contain high level of mineral nutrients such as sodium, zinc, iron and aluminum. Indigenous vegetables can also contain an appreciated amount of vitamins and proteins (Mnzava, 1997). On average 100g of fresh vegetables contain levels of calcium, iron and vitamins that would provide 100% of the daily requirement and 40% for the protein (Abukutsa-Onyango, 2003). The ILVs were also shown to contain higher mineral nutrients compared to exotic vegetables. Mariga *et al.,* (2012) reported that swiss chard vegetable contained 0.78% calcium content which is lower compared to spider plant (2.24%), jute mallow (2.46%), blackjack (1.16%), amaranth (2.17%) and nightshade (1.55%), and swiss chard was also low in iron content (288.4 mg/kg) compared to black jack (563 mg/kg) that contained two times that content.

Results from this study indicate that amaranth from Vhembe district has different minerals nutrients as the one from Sekhukhune district (Table 3.7). This may be due to soil types the vegetable is grown on, the weather and the age of the crop. It is also possible that the species could be different. Amaranth from Vhembe district showed to have high mineral nutrient of potassium 5.64% and zinc 318mg\kg whereas amaranth from Sekhukhune have high magnesium 1.05% content. Odhav *et al.,* (2007) found similar concentrations of calcium 2.36% and magnesium 1.31% in *Amaranthus hybridus* a species close to *A. cruentus*. The spider plant showed to be high in sodium 1222.4mg\kg and phosphorus 0.79% but low in potassium 3.14% and molybdenum 50mg\kg. Narrow-leaved vernonia contains high content of copper 25.4mg\kg, iron 1078mg\kg and aluminum 1101mg\kg. Hence, the high value of iron in these vegetables makes them a potential source of iron for vulnerable groups such as children under five and pregnant and lactating women (Kamga *et al.,* 2013). *Cleome monophylla* is high in sodium 6.06%, calcium 3.17% and phosphorus 0.81%. From the results in Table 3.7 it can be seen that all the ILVs tested are good sources of essential nutrients that the human body needs to keep healthy.

Table 3.7: Nutrient analysis of selected ILVs

ILVs and districts collected	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Al (mg/kg)
Amaranth (Vhembe)	3,82	0,42	5,64	2,71	0,84	759,2	318	7,8	220	669	835
Spider plant (Capricorn)	5,59	0,79	3,14	2,24	0,42	1222,4	52	13,7	50	1007	934
Devils thorn (Sekhukhune)	4,63	0,72	3,16	3,17	0,42	328,4	37	9,0	43	486	423
Narrow-leaved vernonia (Sekhukhune)	4,83	0,27	3,57	1,30	0,29	471,4	49	25,4	121	1078	1101
Bitter gourd (Vhembe)	5,53	0,37	3,88	1,60	0,32	1020,7	55	7,6	112	476	541
Blackjack (Vhembe)	4,85	0,49	3,15	1,16	0,30	285,6	94	23,7	133	563	398
Corchorus. monophylla (Sekhukhune)	6,06	0,81	3,71	3,17	0,31	512,9	43	7,6	101	511	499
Amaranth (Sekhukhune)	3,83	0,52	4,33	3,14	1,05	567,9	43	11,4	107	671	613
Jute mallow (Sekhukhune)	4,44	0,71	3,36	2,46	0,37	583,6	38	7,8	113	280	304
Nightshade (Vhembe)	5,35	0,40	4,38	1,55	1,07	2341,5	25	8,9	103	692	867

Abbreviation: N= Nitrogen, P= Phosphorus, K= Potassium, Ca = Calcium, Mg= Magnesium, Na= Sodium, Zn= Zinc, Cu= Copper, Mn= Manganese, Fe= Iron, Al= Aluminum

3.3.6 Marketing of ILVs

(a) Marketed products and prices

African indigenous vegetables have considerable potential as cash income earners, enabling the poorest people in the rural communities to earn a better living (Schippers, 2000, Abukutsa-Onyango, 2003). Indigenous vegetables can be grown easily especially by women on small plots and be used to feed household or to generate extra income (Spore, 2004). In the current study, the marketing practices of these vegetables differ according to areas (Table 3.8). These ILVs are marketed informally, as they are sold locally by the community members. Socio-economic survey on traditional vegetables conducted in various parts of Africa, particularly in Central, Western and Eastern Africa (Abukutsa-Onyango, 2002; Schippers 2000), revealed that indigenous vegetables are important commodities in household food security. From all the identified ILVs only few are being sold and the marketing is mostly active during winter as most ILVs are not available in the field. Most of the communities sell the ILVs that are stored during rainy season. These vegetables are sold as dried leaves while others are sold as cooked dried leaves. Some are also sold as fresh leaves at the time they are found in the field.

Selling of vegetables differs among areas and also the quantities the vegetables are measured in differ according to types of vegetables and this also influences the price. Most of these vegetables are sold as dried vegetables in containers, as they have short fresh life span while few are sold as fresh leaves in bunches. Blackjack, amaranth, pumpkin, cowpea and spider plant are the most common ILVs sold in the three districts. Spider plant, pumpkin, amaranth, bitter gourd and black jack are sold as fresh leaves and also as cooked dried leaves. Nightshade is grown under irrigation in Vhembe as a commercial crop and is commonly sold by roadside vendors and local supermarkets in fresh leaf bundles. The prices of sold ILVs shown in Table 3.8 show that the ILVs are much more affordable compared to most of the exotic vegetable and sold meat in supermarket, therefore people are encourage buy these ILVs because they are affordable.

TABLE 3.8: Marketing practices and prices of ILVs in the three districts

DISTRICT	ILVS MARKETED
COWPEA	
Capricorn	The cowpea vegetable was sold as cooked dried leaves without salt. The vegetable was sold at different price in different quantities. • One cup (250ml) is sold for R5.00 • 1kg bucket is sold at R40.00
Sekhukhune	It was also sold as cooked dried leaves like in Capricorn district. • One cup (250ml) is sold at R10.00 • 2kg bucket is sold at R35.00 • 1 snack plastic is sold for R15.00
Vhembe	Same as above but with different price • One cup (250ml) is sold for R10.00 like in Sekhukhune district • 1kg bucket is sold for R20.00
SPIDER PLANT	
Capricorn	The spider plant was sold as cooked dried leaves like cowpea. The spider plant can also be mixed with amaranth. • One cup (250ml) costs R10.00 • 1kg bucket costs R20.00 Fresh leaves of spider plant and amaranth are sold R7.00 in a 2kg bucket
Sekhukhune	Sold the same as in Capricorn district
Vhembe	Spider plant was sold as fresh leaves in bunches

	• 1 bunch costs R10.00 As a cooked dried vegetables • 1kg bucket costs R10.00
PUMPKIN	
Capricorn	The pumpkin can be sold as fresh leaves and also as cooked dried leaves. • 1 bunch costs R4.00 • 1 plastic full of fresh leaves costs R8.00 • One cup (250ml) of cooked dried leaves costs R10.00
Sekhukhune	The pumpkin was sold only as cooked dried leaves in this district with the same price of 1 cup as in Capricorn district and 2kg bucket at R20.00
Vhembe	In this district, the pumpkin was sold only as fresh leaves packed in bunch. • 1 bunch costs R10. 00 or R5.00 depending on the seller
AMARANTH	
Capricorn	Amaranth was sold as fresh leaves or as cooked dried leaves. • 1 cup (250ml) of cooked dried leaves costs R10.00
Sekhukhune	Amaranth was sold in the same form as in Capricorn district • One bunch costs R5.00 • 1 cup (250ml) of cooked dried leaves costs R10.00
Vhembe	Amaranth was only sold as fresh leaves • 1 bunch costs R10.00

BLACK JACK	
Capricorn	Black jack was sold as cooked dried leaves • 1 bunch costs R10.00
Vhembe	Black jack was sold either as fresh leaves or cooked dried leaves • 1 bunch of fresh leaves costs R5.00 • 1kg bucket cost R5.00
PUMPKIN	
Capricorn	Pumpkin was sold as dried leaves • 1 cup (250ml) costs R10.00
TSAMMA (melon)	
Sekhukhune	Tsamma was sold in the same form like cucurbit with the same price and quantity
NARROW-LEANED VERNONIA	
Capricorn	Was sold as cooked dried leaves • 1 cup (250ml) costs R10.00
NIGHTSHADE	
Vhembe	Nightshade was sold as fresh leaves • 1 bunch costs R5.00 to R10.00
JUTE MALLOW	
Sekhukhune and Vhembe	Jute mallow was sold in the two districts as dried leaves • 1 kg bucket cost R10.00
BITTERGOURD	

Vhembe	Bitter gourd was sold as fresh leaves and also as cooked dried leaves. • 1 bunch of fresh leaves costs R5.00 • 1kg container costs R10.00

(b) Reasons why the utilization and marketing of ILVs is increasing or decreasing compared to the previous years

During the survey, farmers were also asked a question on whether there was a decrease or increase in the consumption of ILVs compared to the previous years (Table 3.9). The introduction of exotic vegetables had some negative impact on the consumption and domestication (cultivation) of indigenous vegetables. Most of the farmers indicated that there is a decrease in the use of these vegetables, this may be due to the fact that most of the younger people are no longer interested in eating these indigenous vegetables as they prefer mostly the exotic ones. The introduction of exotic vegetables contributed to the decline in the production and consumption of indigenous vegetables. Maziya-Dixon *et al*., (2004) reported that in Nigeria, leafy vegetables are relatively readily available and affordable, particularly during the rainy seasons, but were found to be among the least consumed foods. However, the reasons presented in Table 3.9 suggest that due to health consciousness being promoted, there is now a rising demand for some of these ILVs. The nutritional profiles given in Table 3.7 clearly show that there is scope for promotion of the consumption of these vegetables.

TABLE 3.9: Reasons for increase or decrease of ILVs in terms of utilization and marketing in the different districts

CAPRICORN DISTRICT	
Increase	Decrease
• Most people are sick and doctors encourage them to eat vegetables.	• Most people are no longer involved in farming practices.

• Some people prefer ILVs because of their high nutrient content. • Because of food insecurity, most people rely on ILVs for feeding as they are easily accessed.	• Most of youth are no longer interested in consuming ILVs. • Most of the people lack knowledge about the nutritional content of these ILVs so they prefer exotic vegetables.
SEKHUKHUNE DISTRICT	
Increase	Decrease
• Most of people are sick and they start consuming these indigenous vegetables. • Most of people are aware of their high nutrient content. • Most people no longer prefer refrigerated food.	• Farming has been reduced compared to the previous years and most of youth are not familiar with the vegetables. • Most youth prefer to eat meat.
VHEMBE DISTRICT	
Increase	Decrease
• Some are aware of their nutritional content so they eat them for their health benefit. • Medical advisers are encouraging people to eat ILVs.	• Few people, especially elder ones are the only one eating vegetables compare to younger ones. • Because they associate people who eat vegetables as poor. • People who are producing these vegetables are few. • People prefer to eat the exotic vegetables than the indigenous ones.

3.3.7 Preferred ILVs found in the three districts

From the cultivated and uncultivated ILVs there are some that are mostly preferred by the communities in the identified districts (Table 3.10). These may be due to the taste they have, their high nutritional content, level of availability, production management and their medicinal and cultural uses. Most of the preferred vegetables are being cultivated by the community members, in order for them to get these vegetables in large quantities. Farmers in Capricorn district identified 10 ILVs which they mostly preferred, 12 in Sekhukhune district and 9 in Vhembe district. The preferences of these vegetables differ according to districts but amaranth was mostly preferred across all the three districts. Most ILVs preferred in Sekhukhune district are similar to the ones preferred in Capricorn district these may be because both the districts are mainly occupied by Pedi people, so they have common preferences.

In Capricorn district, results show that there are five mostly preferred ILVs which are; spider plant, cowpea, pumpkin, Amaranth and wild cucumber, with preference levels of 83.3%, 31.25%, 29.2%, 50% and 27.1% of the respondents, respectively. , In Sekhukhune district the preference level were 92%, 26%, 22%, 90%, 48%, 34% and 28% for spider plant, cowpea, pumpkin, *Amaranthus* spp., jute mallow, *V. fastigiata* and tsamma, respectively. In Vhembe district respondents mostly preferred pumpkin (28.5%), *Amaranthus* spp. *(*54.7%*),* jute mallow (40.4%), blackjack (57.2%), *C. monophylla* L (23.8%), nightshade (59.5%) and bittergourd (28.5%). In all the three districts spider plant, jute mallow, pumpkin and *Amaranthus* spp., were the mostly preferred ILVs. Shackleton *et al.* (1998) found in a study of uncultivated TLVs in Bushbuckridge that *Corchorus spp* (90%), *Cleome gynandra* (82%), *Momordica balsamina* (76%) and *Amaranthus spp* (59%) were the popular TLVs used.

TABLE 3.10: ILVs that are mostly preferred by the communities in the three districts

COMMON AND BOTANICAL NAMES OF ILVS	CAPRICORN DISTRICT (%) (N=135)	SEKHUKHUNE DISTRICT (%) (N=134)	VHEMBE DISTRICT (%) (N=135)
Spider plant	83.3	92	19
Cowpea	31.25	26	-
Pumpkin	29.2	22	28.5
Amaranthus spp	50	90	54.7
P viscosa	12.5	12	-
Melon	27.1	10	-
Jute mallow	10.4	48	40.4
V fastigiata	10.4	34	-
Rattle pods	8.4	-	-
Tsamma (melon)	8.4	28	7.2
Devil's thorn	-	16	-
Blackjack	-	6	57.2
Cleome monophylla L.	-	-	23.8
Nightshade	-	-	59.5
Bitter gourd	-	-	28.5

From the results in Table 3.10, it shows that several respondents consume more than one ILV. It is shown that Capricorn and Sekhukhune district farmers/communities prefer spider plant and amaranth as their regular vegetables while those in Vhembe district prefer nightshade, black jack and Amaranthus species. Both spider plant and nightshade vegetables are important as they are produced for both domestic consumption and commercial purposes. Comparing the market potential of the two vegetables, nightshade was chosen as one with the highest market potential because it can be found in formal supermarkets as well as informal markets (street vendors). Regardless of its importance, the crop has limited local research in terms of its agronomic management. Its recommended production practices are largely based on those from East Africa. There is therefore a need to develop production practices for the local species under local conditions.

CHAPTER 4

GROWTH AND YIELD OF NIGHTSHADE (*Solanum retroflexum)* IN RESPONSE TO PLANTING DATE AND PLANTING DENSITY

4.1 Introduction

Population density, whether operating directly on the plant or indirectly on biotic factors associated with plant density, is one of the most important factors in determining plant growth and other important agronomic attributes of a crop (Meyer, 1970). In many leafy vegetables, plant spacing is known to have an important effect on yield and quality of the produce and needs to be optimized (Muchiri, 2004). Currently, there are no firm spacing recommendations for production of *S. retroflexum* in South Africa. Mokwele (2009) reported that farmers at Tshiombo irrigation scheme in Vhembe indicated that they plant *S. retroflexum* in rows 40 to 60 cm apart and use intra-row spacing of 15-25 cm. Some farmers in Vhembe, plant at a very high density in 30 cm rows at 5-7.5 cm spacing between plants (Ramugumo, personal communication). The Department of Agriculture, Forestry and Fisheries (DAFF) recommends a plant spacing of 30 cm x 30 cm for nightshade (*S. retroflexum*) (DAFF, 2013). The Food and Agricultural Organization of the United Nations recommends inter-row spacing of 30-60 cm and intra-row spacing of 15-50 cm (FAO, 1988), recognising the diversity in growth habits in the genus Solanum.

Planting times of *S. retroflexum* in Vhembe are also variable (Mokwele, 2009) but farmers try to grow the crop in the cooler part of the year. The planting times in Vhembe informed the times tried in this trial for the Syferkuil farm environment.

A study of responses to plant density therefore considered time of planting as well. This chapter thus presents the results of a trial that tested the effect of plant density and planting dates on growth and leaf yield of nightshade.

4.2 Materials and methods

4.2.1 Site of the study

The experiment was conducted at Syferkuil Agricultural Experimental Farm (23°59’35’’ S; 29°33’46’’ E) of the University of Limpopo, in the Limpopo Province of South Africa. The farm has loamy sand soil and the climate of the area is classified as semi-arid with summer rainfall occurring from October to March and a pronounced dry spell during winter. The annual average rainfall for the area is between 410 to 500 mm, and the average temperatures reach about 21 to 22 ^{o}C in January and fall to 11^{o}C in July (Thabang *et al.,* 2013).

4.2.2 Experimental design and layout

The experiment was laid out in a randomised complete block design as a 3 x 4 factorial arrangement with three replications. The treatment factors were 3 inter-row spacings of 30, 45 and 60cm and 4 intra-row spacings of 7.5, 15, 22.5 and 30cm (Table 4.1). These treatments encompass plant densities from 444,444 to 55,555 plants per hectare. Plot size was 1.8 m wide x 3.6 m long.

Table 4.1: Treatments of the experiment

Treatments	Plants per hectare	Plants per plot
30 x 7.5 cm	444,444	288
45 x 7.5 cm	296,296	192
60 x 7.5 cm	222,222	144
30 x 15 cm	222,222	144
45 x 15 cm	148,148	96
60 x 15 cm	111,111	72
30 x 22.5 cm	148,148	96
45 x 22.5 cm	98,765	64
60 x 22.5 cm	74,074	48
30 x 30 cm	111,111	72
45 x 30 cm	74,074	48
60 x 30 cm	55,555	36

4.2.3 Soil sampling

Soil samples were collected using an auger at six points across the experimental area prior to the establishment of the trial at depths of 0-30 and 30-60 cm. The samples were taken to the Soil Science laboratory at the University of Limpopo to determine soil chemical properties such as soil pH, soil organic carbon, phosphorus

(P) and mineral nitrogen (N). Soil pH was determined using a pH meter with a glass electrode where 2.5:1 water and KCL soil suspensions were used, Organic carbon was determined following Walkley-Black method (Walkley and Black, 1943), Mineral N (NO_3^- and NH_4^+) was determined using Colorimetric method (Okalebo *et al.,* 2002) and Bray 1 method was used to determine P (Bray and Kurtz, 1945).

4.2.4 Seedbed preparation

Seedbeds were prepared for the production of seedlings for trial establishment (Figure 4.1). A spade and a rake were used during the preparation of the seedbeds, whereby a spade was used to break the clods and a rake was used to level the soil. Stones and plant debris were removed by hand. Rows were opened using a forefinger on the prepared seedbeds. Seeds of nightshade were sown in each row and then covered with a thin layer of soil. The seedbeds were irrigated 3 times a week in the morning using a watering can fitted with a rose. Seedlings emerged 12 days after sowing seeds (Figure 4.2).

Figure 4.1: Prepared seedbeds with opened rows to sow seeds

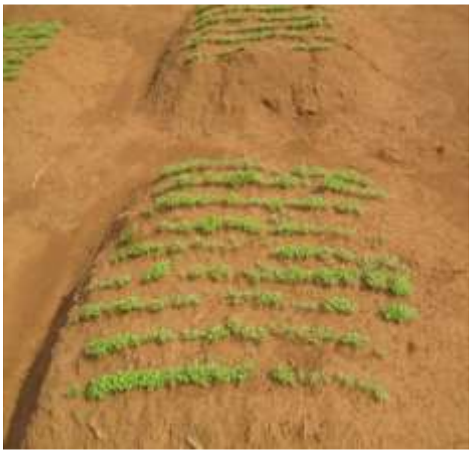


Figure 4.2: Seedbed showing emerged seedlings

4.2.5 Seedling transplanting

Transplanting of seedlings was done 4 weeks after seedling emergence. The seedbeds were irrigated before the seedlings were removed after loosening the soil with a fork. Healthy vigorous seedlings were selected and used during the establishment of the experiment. The seedlings were at a height of 9 to 11 cm, having 5 to 8 true leaves. The seedlings were transplanted in irrigated plots and adequate water was applied soon after transplanting to minimise transplanting shock.

4.2.6 Management and harvesting of the plants

Insect pest infestation and disease incidence were monitored and remedial actions were taken as necessary. Weed control was done by hand-hoeing after every 2 weeks. The plants were irrigated in the morning two and three times a week for 2 hours using sprinkler irrigation during both seasons. The critical measurements were made on the two inner rows. Harvesting was done 5 weeks after transplanting and again four weeks later. At first harvesting the entire shoot was removed by cutting the plant stem 5 cm above the soil surface as recommended by Edmonds and Chweya (1997) and again next to the ground level.

S. retroflexum vegetables grow well in cool temperatures with the optimal varying between 20°C and 30°C, but most Solanum species can grow within a range of 15°C and 35°C and are sensitive to frost. So delayed planting in 2014 growing season resulted in one harvest due to frost that destroyed all the plants at 2 weeks after first harvest (Figure 4.3). So early planting was considered in the next (2015) growing season.

Figure 4.3: *S. retroflexum* plants killed by frost

4.2.7 Data collection

Plant height and plant vigour (health) were assessed at 2 weeks after transplanting, 5 weeks after transplanting and again at 7 and 10 weeks after transplanting (WAT). Plant height was determined by measuring from the base of the stem to the tip of the longest shoot using a tape measure. Plant vigour was measured at 2 and 5 weeks after transplanting in 2014 season and in 2015 was measured at 2, 5, 7 and 10 weeks after transplanting using a green seeker (handheld crop sensor- Trimble). The green seeker was held 60 cm above the crop, when the trigger was pulled then the reading appears on the display screen (Figure 4.4.). At each harvesting number of leaves per plant, number of branches per plant and fresh leaf yield were recorded. Number of leaves and branches were counted per plant on five plants. Fresh leaf yield was measured using a weighing balance.

Figure 4.4: Measuring plant vigour using a hand-held green seeker

4.2.8 Data analysis

All recorded data were subjected to analysis of variance (ANOVA) using the STATISTIX 10.0 package and treatment mean separation was done using the Turkey HSD at 5% probability level.

4.3 Results and discussion

4.3.1 Soil chemical properties

The chemical properties (pH, Organic carbon, phosphorus and mineral N) of soils prior planting collected at a depth of 0-30 cm and 30-60 cm for both the two planting seasons are presented in Table 4.2. The soil pH of the top soil for both the planting seasons was slightly alkaline, with pH ranging from 7.2 to 7.81 while the bottom soil was mildly acidic with a pH ranging from 6.17 to 6.33. The soil was low in organic matter and mineral nitrogen but had high level of available phosphorus.

Table 4.2: Soil analysis results at depths of 0-30 cm and 30-60 cm

2014 (April to May)		
	0-30 cm	30-60 cm
Soil pH (KCL 2.5:1)	7.81	6.33
Soil pH (H2O 2.5:1)	7.2	6.32
Organic carbon (%)	0.74	0.55
Phosphorus (mg\kg)	62.87	52.19
Mineral nitrogen (mg\kg)	0.11	0.27
2015 (March to May)		
	0-30 cm	30-60 cm
Soil pH (KCL 2.5:1)	7.61	6.17
Soil pH (H2O 2.5:1)	7.44	6.22
Organic carbon (%)	1.22	0.62
Phosphorus (mg\kg)	55.71	47.50
Mineral nitrogen (mg\kg)	0.12	0.78

4.3.2 Plant height and vigour per plant

Plant height is an important component that helps in determining the growth of the plant attained during the growing period. Results showed that plants were taller with higher plant density. Plants grown with closer spacing were found to be taller than those grown with wider spacing. Kyeraa (2003) reported that although spacing did not significantly affect plant height, closer spacing produced taller plants and the highest total number of fruits per plant and per hectare in eggplant (ravaya).

The results showed that plant height was not significantly affected by inter-row spacing in both plantings in 2014 and in 2015 season, except at 7 weeks after transplanting (WAT) in 2015 season (Table 4.3). At that harvest 30 cm spacing produced plants of 20.6 cm which were significantly taller when compared to plant height of 17.1 cm produce at 60 cm spacing. Plant height with the intra-row spacings differed significantly in 2014 season at both 2 and 5 WAT and only at 2 WAT in 2015 season and no significant differences were found in 2015 at 5 WAT, 7 WAT and at 10 WAT and 10 WAT (Table 4.4). From the intra-row spacing it was observed that closer spacing of 15 cm produced the tallest plants when compared to the other spacings of 7.5, 22.5 and 30 cm spacing; however 7.5 cm, which was the closest spacing, produced taller plants when compared to 22.5 and 30 cm. Therefore this suggests that nightshade prefers closer spacing but not too close to maximize on plant height. Close spacing results in high plant density that can reduce temperature between the plants as this crop requires cooler temperature for maximum production. This was supported by Edmond and Chweya (1997) that the optimum temperature for nightshade regime varies and also stated that *S. nigrum* species could tolerate up to 60 % shading. Vander Zaag *et al.,* (1990) on the influence of plant spacing on potato (*Solanum tuberosum* L) morphology, growth and yield under two contrasting environments showed that plant height was initially similar with all treatments but after 72 days the closely spaced plants were taller than the wider spaced ones. Inter-row and intra-row spacing showed significant interaction on plant height in 2014 season at 5 WAT and in 2015 season at 2 WAT. Taller plants of 37.6 cm were produced at 45 x 15 cm while height of 25.67cm was produced at 30 x 7.5 cm. However, tallest plants were found in 2015 season at 10 WAT. This could be due to the changing of temperatures. DAFF (2013) reported that nightshade plants require temperatures between 20 to 34^{o}C and frost free conditions to maximize production.

Plant vigour showed no significant differences in both seasons with inter-row spacings. However, significant differences were found at 5 weeks after transplanting in 2015 season. Plants grown at inter-row spacings of 30 and 45 cm produced more vigorous plants than those grown with a spacing of 60 cm. With intra-row spacing, significant differences were observed in the 2014 season at both 2 weeks and 5 WAT and in the 2015 season at 5 WAT. From the interaction, significance differences were found in the 2014 season at both 2 and 5 WAT and in 2015 season 5 and 10 WAT. It was observed that plants close to each other were more vigorous than those grown at a wider spacing. This may be due to the fact that *S. retroflexum* vegetables are more sensitive to too much high temperature, therefore closer spacing produces more plants that may shade each other and result in cooler canopy temperature. This is supported by Kyeraa (2003) who worked on the effects of spacing and weeding frequency on growth and yield of eggplant, and stated that closer spacing produced wider canopy and the highest total number of fruits per plant and per hectare.

Table 4.3: Effect of inter-row spacing on plant height and plant vigour on *S. retroflexum*

2014 (April to May)					2015 (March to May)							
Inter-row (cm)	Plant height (cm)		Plant vigour (NDVI)		Plant height (cm)				Plant vigour (NDVI)			
	2 WAT	5 WAT	2 WAT	5 WAT	2 WAT	5 WAT	7 WAT	10 WAT	2 WAT	5 WAT	7 WAT	10 WAT
30	26.28a	31.03a	0.63a	0.74a	21.83a	31.75a	20.6a	43.23a	0.42a	0.75a	0.61a	0.81a
45	24.15a	30.85a	0.62a	0.72a	20.87a	32.52a	17.7ab	39.39a	0.48a	0.76a	0.6a	0.80a
60	25.30a	31.01a	0.60a	0.72a	19.93a	30.1a	17.1b	38.36a	0.43a	0.73a	0.53b	0.69b
Significance	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	*	*
Turkey $HSD_{0.05}$	-	-	-	-	-	-	3.08	-	-	-	0.07	0.07

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, ns=non-significant,* significant at P≤0.05, 2 WAT= 2 weeks after transplanting, 5 WAT= 5 weeks after transplanting, 7 WAT = 7 weeks after transplanting, 10 WAT= 10 weeks after transplanting.

Table 4.4: Effect of intra-row spacing on plant height and plant vigour

2014 (April to May)					2015 (March to May)							
Intra-row (cm)	Plant height (cm)		Plant vigour (NDVI)		Plant height (cm)				Plant vigour (NDVI)			
	2 WAT	5 WAT	2 WAT	5 WAT	2 WAT	5 WAT	7 WAT	10 WAT	2 WAT	5 WAT	7 WAT	10 WAT
7.5	26.07ab	32.24ab	0.67a	0.76a	22.28ab	34a	19.11a	40.37a	0.5a	0.72b	0.61a	0.81a
15	27.98a	35.31a	0.65ab	0.76a	22.73a	31.33a	19.13a	45.08a	0.47a	0.79a	0.61a	0.8a
22.5	22.02b	26.09c	0.54c	0.72ab	19.78ab	30.33a	18.78a	38.42a	0.41a	0.74ab	0.55a	0.72a
30	24.91ab	30.22bc	0.59bc	0.66b	18.711b	30.16a	16.95a	37.44a	0.38a	0.72b	0.56a	0.74a
Significance	*	**	*	*	*	Ns	Ns	Ns	Ns	*	Ns	Ns
Tukey $HSD_{0.05}$	5.46	4.36	0.06	0.06	-	-	-	-	-	0.06	-	-

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, ns=non-significant, ** significant at P≤0.05,* significant at P≤0.05, 2 WAT= 2 week after transplanting, 5 WAT= 5 week after transplanting, 7 WAT = 7 weeks after transplanting, 10 WAT= 10 weeks after transplanting.

Table 4.5: The interactive response to inter and intra-row spacing of plant height and plant vigour

2014 (April to May)						2015 (March to May)							
Spacing (cm)		Plant height (cm)		Plant vigour (NDVI)		Plant height (cm)				Plant vigour (NDVI)			
Inter-row	Intra-row	2 WAT	5 WAT	2 WAT	5 WAT	2 WAT	5 WAT	7 WAT	10 WAT	2 WAT	5 WAT	7 WAT	10 WAT
30	7.5	28.33a	31.80abc	0.72a	0.79a	25.67a	35.73a	22.60a	47.50a	0.55a	0.78a	0.67a	0.89a
	15	28.33a	33.87abc	0.64abc	0.75ab	21.27ab	31.00a	20.53a	43.80a	0.41a	0.74ab	0.62a	0.80ab
	22.5	20.17a	26.20bc	0.53bc	0.67ab	18.40ab	29.27a	20.93a	39.60a	0.33a	0.73ab	0.56a	0.76ab
	30	28.40a	32.27abc	0.61abc	0.74ab	22.00ab	31.00a	17.26a	42.03a	0.38a	0.74ab	0.60a	0.804ab
45	7.5	26.33a	33.20abc	0.66abc	0.77ab	21.47ab	37.47a	17.60a	35.06a	0.5a	0.77ab	0.60a	0.83ab
	15	26.47a	37.60a	0.68ab	0.76ab	23.20ab	30.60a	22.00a	50.65a	0.55a	0.83a	0.65a	0.85ab
	22.5	21.00a	24.13c	0.52c	0.63b	21.13ab	32.47a	18.60a	38.56a	0.48a	0.74ab	0.55a	0.75ab
	30	22.80a	31.60abc	0.61abc	0.71ab	17.67ab	29.53a	13.80a	33.31a	0.38a	0.69ab	0.57a	0.77ab
60	7.5	23.53a	31.73abc	0.64abc	0.72ab	19.73ab	28.80a	17.13a	38.53a	0.45a	0.63b	0.52a	0.72ab
	15	29.13a	34.47ab	0.65abc	0.77ab	23.73ab	32.40a	15.93a	40.80a	0.45a	0.79a	0.57a	0.77ab
	22.5	25.00a	27.93abc	0.57abc	0.68ab	19.80ab	29.27a	16.60a	37.10a	0.42a	0.75ab	0.53a	0.65b
	30	23.53a	26.80bc	0.55bc	0.70ab	16.47b	29.93a	19.80a	37.00a	0.4a	0.72ab	0.50a	0.65b
Significance		Ns	**	*	*	*	Ns	Ns	Ns	Ns	*	Ns	*
Tukey $HSD_{0.05}$		-	9.9019	0.15	0.15	8.76	35.73a	-	-	-	0.14	-	0.21

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, ns=non-significant, ** significant at P≤0.05,* significant at P≤0.05, 2 WAT= 2 week after transplanting, 5 WAT= 5 week after transplanting, 7 WAT = 7 weeks after transplanting, 10 WAT= 10 weeks after transplanting.

4.3.3 Number of leaves produced per plant

The number of leaves was not significantly affected by inter-row spacing in both 2014 and 2015 at both 5 and 10 WAT. However, closer spacing resulted in more leaves than wider spacing. This was unexpected but was similar to Mari *et al.,* (1997) and Rizk (1997) who reported that lower planting density resulted in higher number of leaves per plant. In 2014 and 2015 seasons, number of leaves was not significantly affected by intra-row spacing at P≤0.05, however, 15 cm spacing produced the highest number of leaves in 2014 season and 2015 season at 5 WAT and at 10 WAT. The results showed that the interaction between inter and intra-row spacings significantly influenced number of leaves in 2014 season with 30 cm x 15 cm producing the highest number of leaves of 145 and 30 cm x 22.5 cm producing the least number of leaves of 61 per plant. FAO (1988) reported that at least a spacing of 15 to 25 cm should be left in-row to encourage leaf production. Mokwele (2009) also reported that farmers at Tshiombo irrigation scheme indicated that they plant nightshade at a spacing of 15- 25 cm in-row. These results are also supported by one of the farmers at Tshiombo irrigation scheme in Vhembe district who stated that they use a very high plant density of 5-7.5 cm spacing between the plants in the row to produce nightshade vegetable (Ramogumo, personal communication). From a plant development perspective, the results from this study suggest that spacing of 45 cm x 15 cm would maximise leaf production.

4.3.4 Number of branches produced per plant

Number of branches was not significantly affected by inter-row spacing in both 2014 and 2015 at both 5 and 10 WAT. However, intra-row spacing significantly affected number of branches in 2014 and 2015 season at 5 WAT. In 2014, it was observed that 15 cm intra-row spacing gave the highest mean number of branches, higher by 42.85% and 66.67% when compared with 22.5 cm and 30 cm spacing, respectively. In 2015 season at 5 WAT, highest number of branches was found at 15 cm intra-row spacing which was significantly different to 7.5 cm spacing, whereas 22.5 and 30 cm were identical. The interaction between inter-row and intra-row spacings showed significant differences in both number of branches and leaves in 2014, but in 2015 season only number of branches at 5 WAT was significantly affected. In 2014, it was found that 45 cm x 15 cm gave the highest number of branches, which was significantly superior to 45 cm x 30 cm that produced the lowest number of branches.

Table 4.6: Effect of inter-row spacing on number of leaves and branches

	2014 (April to May)		2015 (March to May)			
Inter-row (cm)	No of branches	No of leaves	$No of branches	$No of leaves	#No of branches	#No of leaves
30	7a	125a	9a	107a	7a	106a
45	9a	100a	9a	112a	7a	105a
60	9a	99a	8a	94a	7a	92a
Significance	Ns	Ns	Ns	Ns	Ns	Ns
Tukey $HSD_{0.05}$	-	-	-	-	-	-

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, Ns=non-significant, $ = 5 weeks after transplanting, #= 10 weeks after transplanting.

Table 4.7: Effect of intra-row spacing on number of leaves and branches

	2014 (April to May)		2015 (March to May)			
Intra-row (cm)	No of branches	No of leaves	$No of branches	$No of leaves	#No of branches	#No of leaves
7.5	9ab	114a	8b	106a	7a	93a
15	10a	147a	10a	107a	8a	117a
22.5	7b	84a	9ab	103a	8a	113a
30	6b	86a	9ab	104a	7a	79a
Significance	*	Ns	*	Ns	Ns	Ns
Tukey $HSD_{0.05}$	2.68	-	2.07	-	-	-

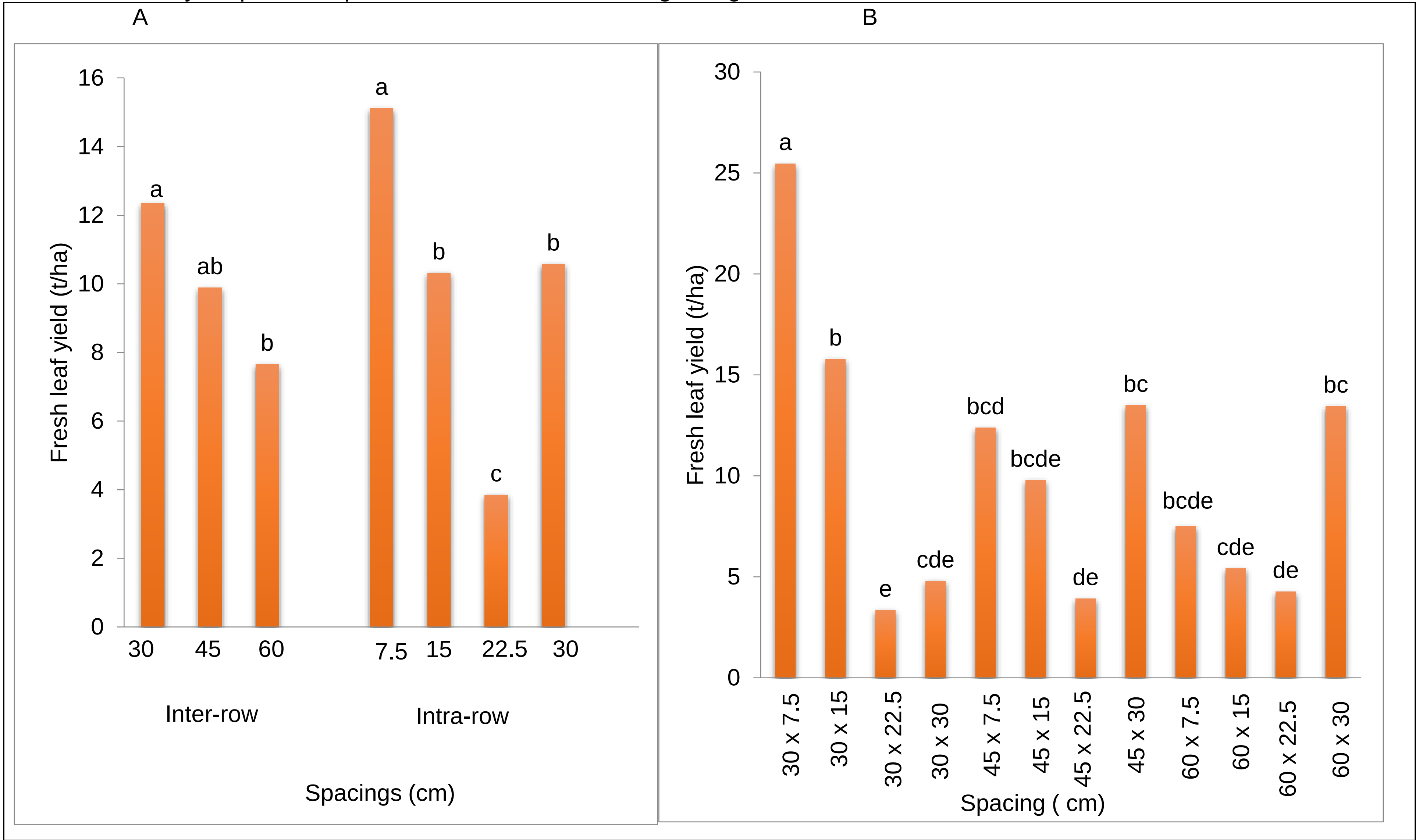
Means in the same column followed by the same letter are not significantly different HSD = Honest Significant Difference, Ns = non-significant,* = significant at P≤0.05, $ = 5 weeks after transplanting, # = 10 weeks after transplanting.

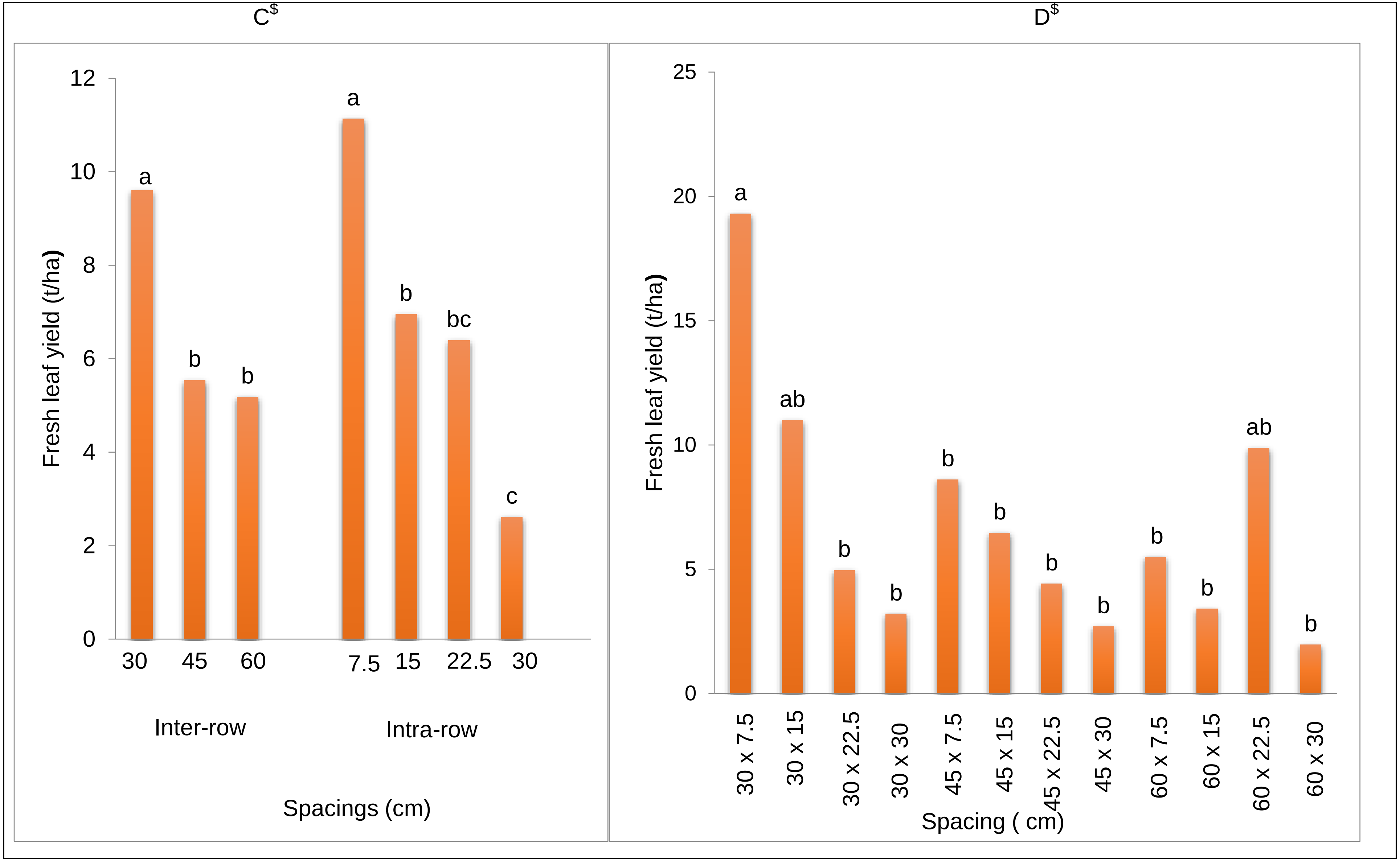
Table 4.8: Interaction effect of inter and intra-row spacing on growth parameters measured at harvest

2014 (April to May)				2015 (March to May)			
Inter-row (cm)	Intra-row (cm)	No of branches	No of leaves	$ No of branches	$ No of leaves	# No of branches	# No of leaves
30	7.5	7ab	109ab	9a	128a	9a	133a
	15	8ab	145a	9a	110a	6a	108a
	22.5	7ab	61b	9a	93a	6a	113a
	30	5ab	85ab	9a	99a	6a	67a
45	7.5	9ab	85ab	8ab	104a	6a	77a
	15	11a	122ab	10a	126a	8a	143a
	22.5	8ab	99ab	9a	126a	8a	126a
	30	4b	77ab	6ab	92a	8a	75a
60	7.5	10ab	101ab	4b	85a	6a	70a
	15	10ab	111ab	8ab	75a	8a	91a
	22.5	5ab	91ab	10a	87a	8a	114a
	30	10ab	96ab	10a	129a	7a	95a
Sig...		*	*	*	Ns	Ns	Ns
Tukey $HSD_{0.05}$		6.08	178.96	4.70	-	-	-

Means in the same column followed by the same letter are not significantly different HSD = Honest Significant Difference, Ns = non-significant,* = significant at P≤0.05, $ = 5 weeks after transplanting, # = 10 weeks after transplanting.

4.3.5 Plant leaf yield produced per hectare in 2014 and 2015 growing seasons




C$
12
10
8
6
4
2
0
Fresh leaf yield (t/ha)
a
b
b
a
b
bc
c
30
45
60
7.5
15
22.5
30
Inter-row
Intra-row
Spacings (cm)
D$
25
20
15
10
5
0
Fresh leaf yield (t/ha)
a
ab
b
b
b
b
b
b
b
b
ab
b
30 x 7.5
30 x 15
30 x 22.5
30 x 30
45 x 7.5
45 x 15
45 x 22.5
45 x 30
60 x 7.5
60 x 15
60 x 22.5
60 x 30
Spacing (cm)

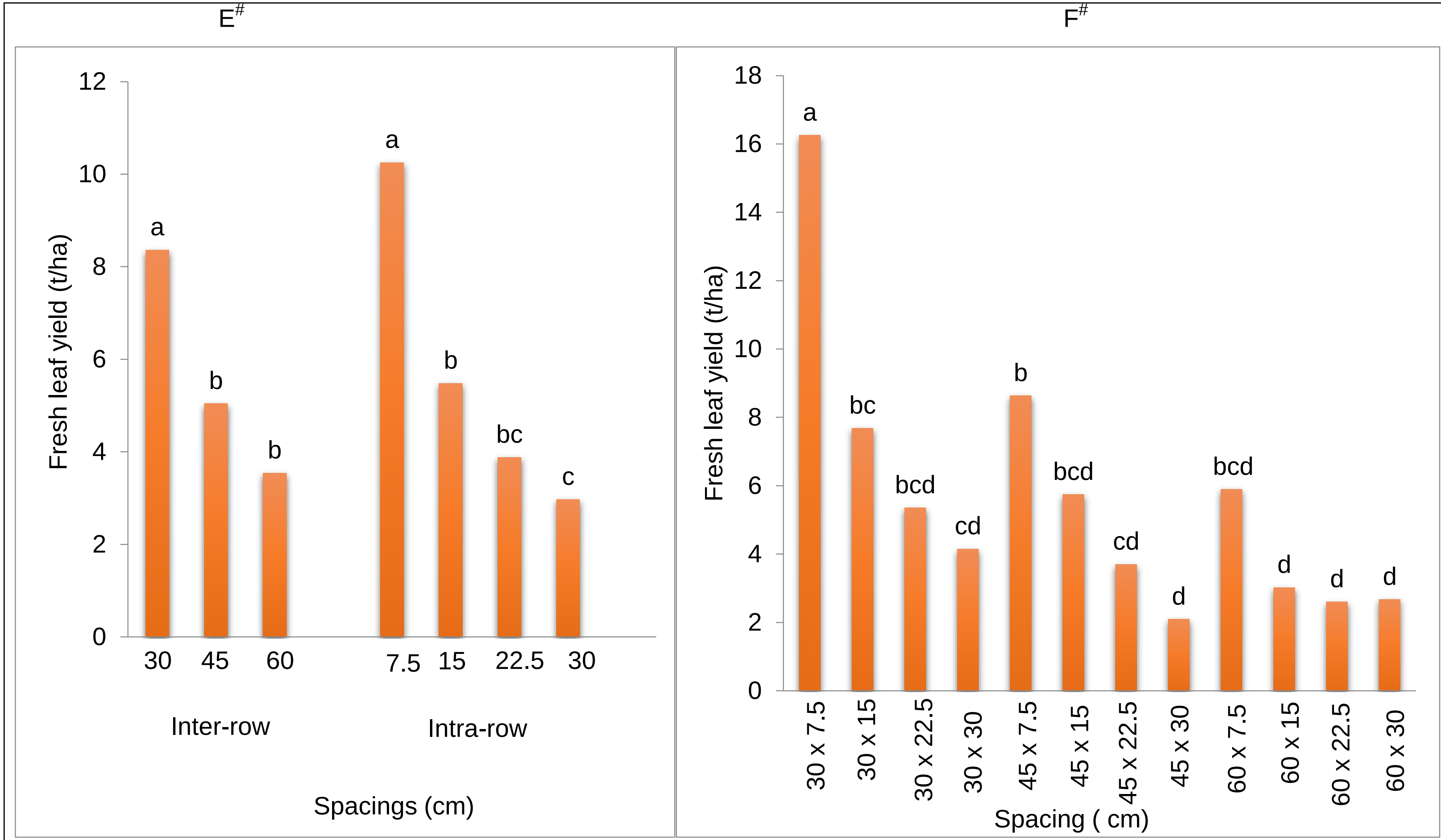


Figure 4.5: Fresh leaf weight produced per hectare in both seasons. Bars followed by the same letter are not significantly different at P≤0.05 C$ and D$= 5 weeks after transplanting for 2015 season, E# and F#= 10 weeks after transplanting for 2015 growing season

Main effects of inter and intra-row spacings had significant effect on fresh leaf yield (Figure 4.5 A, C & E). For inter-row spacing, plants grown at a spacing of 30 cm had the highest fresh leaf weight compared to those that were grown at 45 and 60 cm spacings. In 2014 season, mean leaf yield obtained with 30 cm inter-row spacing was identical to the leaf yield from 45 cm inter-row spacing, but was significantly different to that at 60 cm spacing that gave the lowest yield. Mean leaf weight at 30 cm spacing gave higher yield by 61.3% when compared to 60 cm that gave the least leaf weight. In 2015 season, plants grown at 30 cm spacing produced higher yield weight of 9.6 and 8.36 t\ha at 5 and 10 WAT, respectively, which were significantly different from leaf weight obtained at spacings of 45 and 60 cm. These results support the DAFF (2013) recommendation of 30 cm row spacing for producing maximum nightshade yield. Wider spacing between the plants and rows allows the penetration of the sun between rows that can increase the temperature, which is not favourable for nightshade growth and also increase evaporation that leads to drought problems which affect plant growth. The AVRDC (2003) reported that optimum yields of *S. scabrum* and *S. americanum* were obtained when the crops are planted using an equidistant spacing of 0.30 m, resulting in a planting density of 11 plants m^2. From intra-row spacing results of the current study, it was observed that 7.5 cm spacing produced the highest fresh leaf weight compared to other spacings in both seasons. The results from AVRDC (2003) show considerable differences in response to spacing between species of the Solanum genus. In 2014, 22.5 cm intra-row spacing produced the lowest leaf yield whereas in 2015, 30 cm spacing is the one that produced the least yield. From the results it was found that plants grown with wider spacing produced lowest leaf yield compared to those grown with closer spacing with 2014 season producing more leaf yield than 2015 season. This might be due to different weather conditions that were experienced in both the seasons. It is known that the optimum plant density at one site in one growing season may not apply again in the next growing season because of the variation in weather conditions.

The results also revealed that the interaction between inter and intra-row spacing was significant at $P \leq 0.05$ in both seasons (Figure 4.5 B, D & F). However, the highest fresh leaf yield was found at a spacing of 30 x 7.5 in both experiments. In 2015, fresh leaf yield harvested at 5 WAT were higher than those harvested at 10

WAT and this might be because the second harvest was done towards winter (decreasing temperature) which is not favourable for nightshade production. This finding suggests that many of the *S. retroflexum* growers might be able to increase their yields by raising planting density to 30 cm x 7.5 cm.

4.3.6 Total leaf weight produced in 2015 season

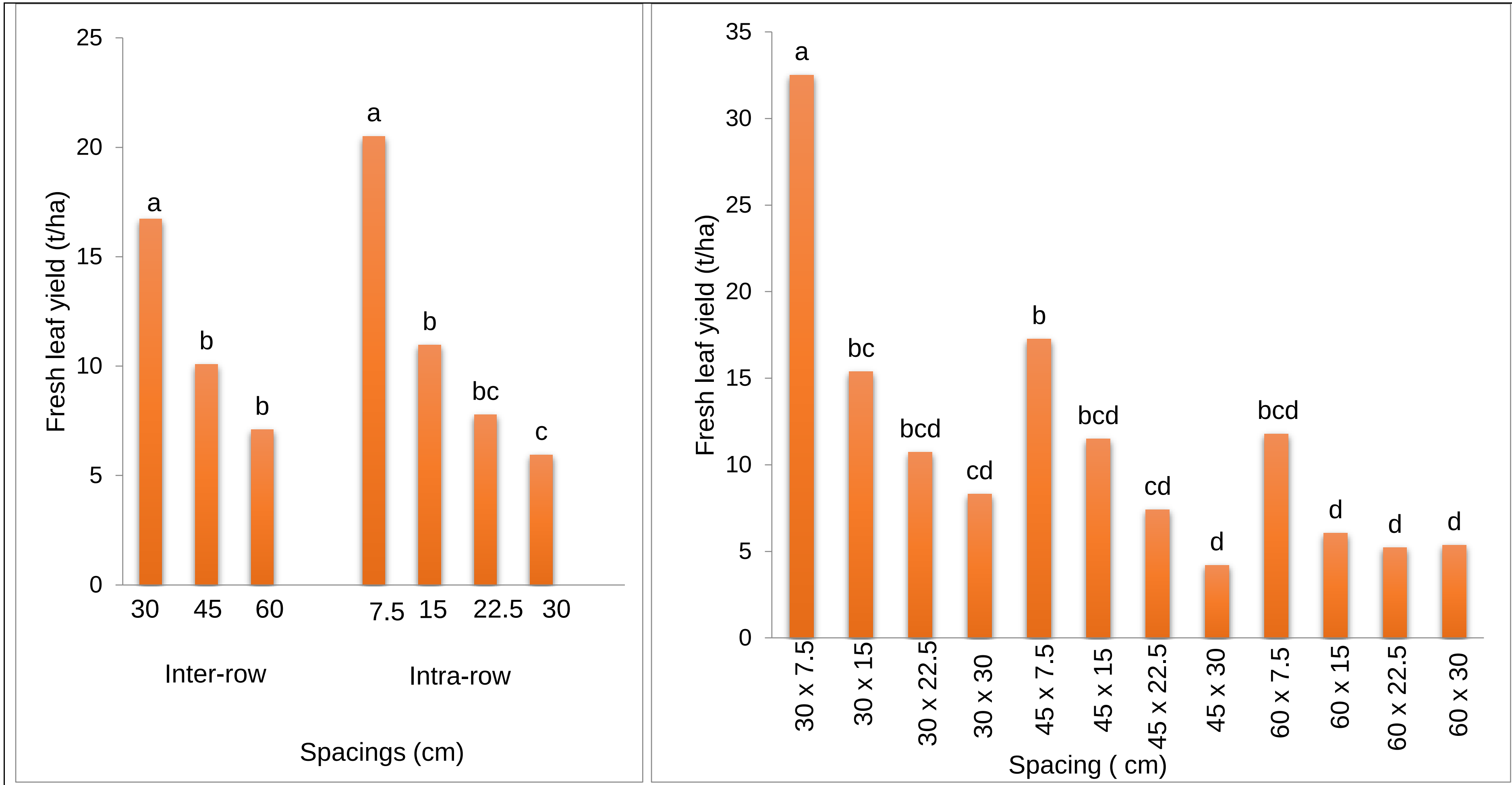


Figure 4.6: Response of spacing to total leaf yield produced in 2015 season. Bars followed by the same letter are not significantly different at P≤0.05

Total leaf yield is the combination of two leaf harvests in one growing season. Therefore, the current results show only the 2015 (5 and 10 WAT leaf yield) growing season due to the frost that killed plants in 2014 growing season before second harvest. Total fresh leaf yield was significantly affected by inter- row and intra-row spacing at $P \leq 0.05$ (Figure 4.6). Mean comparisons revealed that closer spacing produced higher total fresh leaf yield than wider spacing, this followed similar trends of the yields for the harvest periods with yields being high with the closest spacing in both harvests in 2015 season. Total fresh leaf yield tended to decrease with the more open spacing. This was attributed to the plant population which increases as the spacing decreased. Consequently less competition among plants for atmospheric and edaphic resources such as light, water and nutrients under high plant population contributed to high yield, as there would be less competition from weeds (Schippers, 2000). The highest total fresh leaf yields of 16.72 t/ha was produced at 30 cm inter-row spacing with the least yield of 7.09 t/ha produced at 60cm. Intra- row spacing of 7.5 cm gave the highest yield of 20.5 t/ha with the lowest yields of 5.94 t/ha produced at 30 cm spacing.

From the results, total leaf yield was significantly affected by interaction of inter and intra-row spacing (Figure 4.6). An increase in plant density had a positive effect on total leaf yield where 30 x 7.5 cm spacing gave higher yield of 32.508 t/ha and 60 x 22.5 cm gave the lowest leaf yield of 5.206 t/ha. It is therefore advisable to farmers to use closer spacing in order to maximise *S. retroflexum* vegetable production. However, these higher densities would require good water management otherwise moisture stress is likely to adversely affect performance of *S. retroflexum*. The closer spacing also requires high care to avoid crop damage during operations.

CHAPTER 5

GROWTH AND YIELD OF NIGHTSHADE (*Solanum retroflexum*) IN RESPONSE TO INTRA-ROW SPACING, NITROGEN FERTILIZER RATE AND PLANTING DATE

5.1 Introduction

Nightshade (*S. retroflexum*) is one of the important indigenous leafy vegetables (ILVs) which smallholder irrigators produce for consumption and/or commercial purposes. Its growth and yield are influenced by several factors such as plant density, temperature, soil fertility, cultivar and other agronomic management practices. Appropriate plant population can lead to optimum yield, whereas too high or too low plant populations can result in relatively lower yields. Nitrogen is more important than any other elements for plant growth. Onyango (2002) reported that nitrogen promotes growth of leafy vegetables through its effect on cell division, expansion, and elongation. Therefore, this chapter presents a study that tested the effect of nitrogen fertilizer rate and plant density on growth and leaf yield of *S. retroflexum* vegetable.

5.2 Materials and methods

5.2.1 The study was conducted at the same site as the plant density experiment in April to May 2014 and March to May in 2015.

5.2.2 Experimental design and layout

The experiment was carried out in a randomised complete block design with three replications. The treatments were a 6 x 2 factorial arrangement: 6 levels of nitrogen (LAN-28%N) 0, 20, 40, 60, 80 and 100kgLAN/ha and two intra-row spacings of 15 and 30 cm (Table 5.1). Inter-row spacing of 30 cm was used. The plot size was 2.4 m x 3 m length. The nitrogen fertilizer treatments were applied a week after transplanting.

Table 5.1: Treatment combinations of nitrogen fertilizer rate and in-row spacing

TREATMENTS	
Spacing	Nitrogen rates (Kg/ha)
1. 30 x15 cm	0
2. 30 x15 cm	20
3. 30 x15 cm	40
4. 30 x15 cm	60
5. 30 x15 cm	80
6. 30 x15 cm	100
7. 30 x 30 cm	0
8. 30 x 30 cm	20
9. 30 x 30 cm	40
10. 30 x 30 cm	60
11. 30 x 30 cm	80
12. 30 x 30 cm	100

Soil sampling and analysis, general trial management, parameter measurements and data analysis were similar to the plant density experiment.

5.3 Results and discussion

5.3.1 Chemical characteristics of the soil at experimental site

The chemical soil characteristics were determined at depths of 0-30 and 30-60cm before planting (Table 5.2). The soil was analysed for soil pH, organic carbon (%), phosphorus (mg/kg) and mineral N (mg/kg). The top soil pH showed to be slightly acidic in 2014 but the soil in 2015 season, which was determined by potassium chloride (KCL) scale, showed to be slightly alkaline. The organic matter (%) and mineral nitrogen (mg/kg) were low. High level of phosphorus was found in 2014 season whereas in 2015 season the soil showed to have low phosphorus.

Table 5.2: Soil chemical characteristics before planting

2014 (April to May)		
	0-30 cm	**30-60 cm**
Soil pH (KCL 2.5:1)	7.01	6.32
Soil pH (H2O 2.5:1)	7.33	6.32
Organic carbon (%)	0.89	0.76
Phosphorus (mg\kg)	53.94	39.99
Mineral nitrogen (mg\kg)	0.26	0.79
2015 (March to May)		
Soil pH (KCL 2.5:1)	6.33	6.05
Soil pH (H2O 2.5:1)	7.3	6.88
Organic carbon (%)	1.43	0.85
Phosphorus (mg\kg)	26.94	20.13
Mineral nitrogen (mg\kg)	0.54	0.98

5.3.2 Plant height and plant vigour produced per plant

Plant height was not significantly affected by intra-row spacing at P≤0.05 except at 2 weeks after transplanting (WAT) in 2015 where 30 cm produced taller plants of 20.94 cm when compared to 15 cm that produced the shorter plant of 16.83 cm. This was unexpected unless if the trial experienced water shortages soon after transplanting. Nitrogen fertilizer rate significantly (P≤0.05) affected plant height in 2015 growing season at 2 and 10 WAT. At 2 and 10 WAT, plants subjected to 60 kg N/ha produced taller plants than other treatments, but at 2 WAT 0 kg N/ha produced the shortest plants than all the treatments and this might be due to the lack of nutrients in the soil to boost plant growth and at 10 WAT shortest plant height was observed on plants subjected to 100 kg N/ha. From the interaction results, plant height was significantly affected only at 2 WAT in 2015 season with 30 cm x 60 kg N/ha producing the tallest plant of 30.66 cm and 30 cm x 0 kg N/ha produced the shortest plant of 12.33 cm.

Intra-row spacing significantly influenced plant vigour in 2014 season with 15 cm producing more vigorous plants than 30 cm. Nitrogen fertilizer rate significantly affected plant vigour in 2015 season at 5 and 10 WAT. The results reveal that plants subjected to 60 kg N/ha in 2015 season at 5 and 10 WAT produced more vigorous plants by 39.34 and 18.33%, respectively when compared to plants which were not fertilized that produced less vigorous plants. This simply implies that *S. retroflexum* vegetable requires an optimum amount of 60 kg N/ha to grow well and further increase of nitrogen fertilizer has a negative effect on growth and is not economic. From the interaction effect, plant vigour was significantly affected in 2014 season at 2 WAT and in 2015 at 5 and 10 WAT. In 2014 season at 2 WAT, 15 cm spacing with 80 kg N\ha produced more vigorous plants than all the treatments with least vigorous plants produced at 30 cm with 40 kg N/ha. In 2015 at 5 and 10 WAT, more vigorous plants were produced at 15 cm with 60 kg N/ha, lower plant vigour produced at 30 cm x 20 kg N/ha and 30 cm x 40 kg N/ha. This implies that the less nitrogen fertilizer applied with wider spacing the less the vigorous plant is produced, this might be due to insufficient amount of fertilizer for *S. retroflexum* production and the wider spacing makes the crop more exposed to solar heat.

Table 5.3: Effect of intra-row spacing on plant height and plant vigour

	2014 (April to May)				2015 (March to April)				2015 (April to May)			
Intra-row (cm)	Plant height (cm)		Plant vigour (NDVI)		Plant height (cm)				Plant vigour (NDVI)			
	2 WAT	5 WAT	2 WAT	5 WAT	2 WAT	5 WAT	7 WATᴥ	10 WAT#	2 WAT	5 WAT	7 WATᴥ	10 WAT#
15	18.17a	24.06a	0.53a	0.68a	16.83b	37.71a	19.91a	40.27a	0.52a	0.74a	0.49a	0.64a
30	17.38a	22.51a	0.47b	0.61b	20.94a	37.20a	21.25a	41.59a	0.55a	0.71a	0.48a	0.61a
Significance	Ns	Ns	*	*	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Tukey $HSD_{0.05}$	-	-	0.03	0.03	3.36	-	-	-	-	-	-	-

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, ns=non-significant, ** significant at P≤0.05,* significant at P≤0.05, ᴥ= 2 weeks after first harvest, #= 10 weeks after transplanting.

Table 5.4: Effect of nitrogen fertilizer rates on plant height and plant vigour

	2014 (April to May)				2015 (March to April)				2015 (April to May)			
Nitrogen rate (kg/ha)	Plant height (cm)		Plant vigour (NDVI)		Plant height (cm)				Plant vigour (NDVI)			
	2 WAT	5 WAT	2 WAT	5 WAT	2 WAT	5 WAT	7 WAT	10 WAT	2 WAT	5 WAT	7 WAT	10 WAT
0	18.80a	22.07a	0.49a	0.65a	13.16c	33.15a	16.98a	34.81ab	0.46a	0.61c	0.48	0.60b
20	19.03a	24.27a	0.51a	0.65a	15.33bc	37.44a	19.1a	47.44ab	0.57a	0.67bc	0.50	0.62ab
40	18.37a	22.50a	0.48a	0.65a	18.16bc	37a	19.7a	35.66ab	0.51a	0.74abc	0.47	0.59b
60	18.37a	23.77a	0.52a	0.65a	28.83a	47.0a	21.11a	51.33a	0.59a	0.85a	0.52	0.71a
80	16.47a	23.20a	0.50a	0.64a	22.16ab	36.83a	21.15a	46.33ab	0.58a	0.78ab	0.0.45	0.63ab
100	16.57a	23.90a	0.50a	0.67a	15.66bc	33.3a	20.78a	30b	0.49a	0.72abc	0.46	0.60b
Significance	Ns	Ns	Ns	Ns	*	Ns	Ns	*	Ns	*	Ns	*
Tukey $HSD_{0.05}$	-	-	-	-	8.76	-	-	18.89	-	0.15	-	0.09

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, ns=non-significant,* significant at P≤0.05, 2 WAT= 2 week after transplanting, 5 WAT= 5 week after transplanting, 7 WAT= 7 week after transplanting, 10 WAT= 10 week after transplanting.

Table 5.5: The interaction effect of intra-row spacing and nitrogen fertilizer rates on plant height and plant vigour

		2014 (April to May)				2015 (March to April)				2015 (April to May)			
Intra-row (cm)	Nitrogen fertilizer rates (kg/ha)	Plant height (cm)		Plant vigour (NDVI)		Plant height (cm)				Plant vigour (NDVI)			
		2 WAT	5 WAT	2 WAT	5 WAT	2 WAT	5 WAT	7 WAT	10 WAT	2 WAT	5 WAT	7 WAT	10 WAT
15	0	19.47a	23.60a	0.53ab	0.67a	14bc	37.96a	19.13a	37.96a	0.49a	0.64ab	0.52a	0.64abc
	20	17.93a	22.20a	0.53ab	0.65a	11.66c	34.33a	19.26a	47.66a	0.54a	0.72ab	0.53a	0.65abc
	40	20.73a	25.40a	0.55ab	0.72a	15.33bc	37.44a	20.60a	37.33a	0.43a	0.75ab	0.54a	0.66abc
	60	16.60a	23.27a	0.50ab	0.67a	27ab	46.66a	24.8a	55.33a	0.61a	0.88a	0.50a	0.76a
	80	18.47a	25.47a	0.56a	0.69a	18.33abc	36.66a	24.0a	36.66a	0.56a	0.76ab	0.37a	0.56c
	100	15.86a	24.40a	0.50ab	0.70a	14.66bc	33.33a	22.46	26.66a	0.48a	0.71ab	0.42a	0.58bc
30	0	18.13a	20.53a	0.44ab	0.63a	12.33c	28.33a	15.80a	31.66a	0.43a	0.58b	0.44a	0.56bc
	20	20.13a	26.33a	0.48ab	0.65a	19abc	40.55a	17.98a	47.22a	0.59a	0.62b	0.48a	0.60bc
	40	16.00a	19.60a	0.41b	0.57a	21abc	36.66a	18.60a	34a	0.59a	0.72ab	0.40a	0.52c
	60	18.27a	24.27a	0.54ab	0.57a	30.66a	47.33a	20.0a	47.33a	0.58a	0.82ab	0.54a	0.66abc
	80	14.47a	20.93a	0.45ab	0.59a	26abc	37a	22.93a	56a	0.6a	0.81ab	0.54a	0.71ab
	100	17.27a	23.27a	0.49ab	0.63a	16.66abc	33.33a	21.80a	33.33a	0.5a	0.73ab	0.49a	0.61bc
Significance		Ns	Ns	*	Ns	*	Ns	Ns	Ns	Ns	Ns	*	*
Tukey $HSD_{0.05}$		-	-	0.14	-	14.45	-		-	-	-	0.25	0.14

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, ns=non-significant,* significant at P≤0.05, 2 WAT= 2 week after transplanting, 5 WAT= 5 week after transplanting, 7 WAT= 7 week after transplanting, 10 WAT= 10 week after transplanting.

5.3.3 Number of branches and leaves produced per plant

Main effects of intra-row spacing and nitrogen fertilizer rate did not have any significant effect on number of branches and leaves in both seasons. However, 30 cm spacing between the plants tended to produce more branches and leaves than 15 cm spacing in both seasons, therefore nightshade plants prefer 30 cm spacing to produce maximum number of branches and leaves. This was supported by DAFF (2013) that 30 cm x 30 cm plant spacing is recommended to produce maximum growth and yield of nightshade. The Food and Agriculture Organisation of the United Nations (FAO) also stated that a spacing of at least 15 to 50 cm should be left between plants to encourage leaf production (FAO, 1988). Plants subjected to 40 and 60 kg/ha nitrogen in both seasons tended to produce more branches and leaves, and further increase of nitrogen application rates decreased number of branches and leaves in both seasons. Similar results were observed by Olaniyi (2008) who reported an increase in number of leaves of amaranth varieties applied with increasing nitrogen rates from 0 to 60 kg N/ha. A similar trend was also observed by Oliniyi and Ajibola (2008) who observed an increase in *C. olitorius* number of leaves in response to nitrogen application. From the interaction results, intra-row spacing and nitrogen fertilizer rates significantly affected number of branches in 2014 season and 2015 season at 5 WAT and number of leaves were not significantly affected in both seasons. It was observed that the combination of 15 cm spacing x 0 N kg/ha in both seasons had the lowest mean number of branches. This might be due to that the plants did not receive any nutrient to boost their growth.

Table 5.6: Effect of intra-row spacing on growth parameters of *S retroflexum*

	2014 (April to May)		2015 (March to April, 5 weeks after transplanting)		2015 (April to May, 10 weeks after transplanting)	
Intra-row (cm)	No of branches	No of leaves	No of branches	No of leaves	No of branches	No of leaves
15	6a	70a	9b	102a	6a	81a
30	6a	78a	11a	107a	7a	85a
Significance	Ns	Ns	*	Ns	Ns	Ns
Tukey $HSD_{0.05}$	-	-	2.09	-	-	-

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, Ns=non-significant, * significant at P≤0.05

Table 5.7: Effect of nitrogen fertilizer rate on growth parameters of *S. retroflexum*

	2014 (April to May)		2015 (March to April), 5 weeks after transplanting)		2015 (April to May, 10 weeks after transplanting)	
Nitrogen fertilizer rates (kg/ha)	No of branches	No of leaves	No of branches	No of leaves	No of branches	No of leaves
0	5a	73a	7a	79a	5a	44a
20	7a	72a	9a	73a	7a	97a
40	6a	88a	12a	111a	8a	82a
60	6a	77a	11a	139a	8a	111a
80	5a	74a	11a	103a	6a	91a
100	6a	60a	9a	124a	5a	76a
Significance	Ns	Ns	Ns	Ns	Ns	Ns
Tukey $HSD_{0.05}$	-	-	-	-	-	-

Means in the same column followed by the same letter are not significantly different HSD=Honest Significant Difference, Ns=non-significant

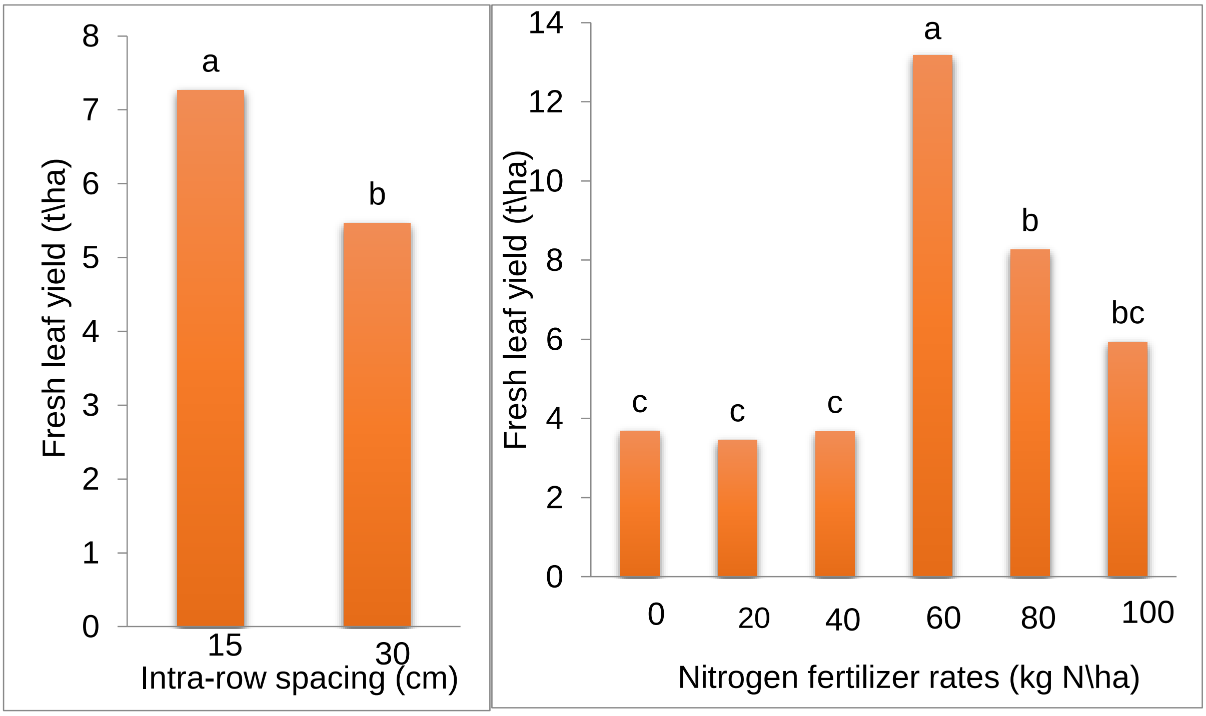
Table 5.8: Interaction effect of intra-row spacing and nitrogen fertilizer rate on growth parameters of *S. retroflexum*

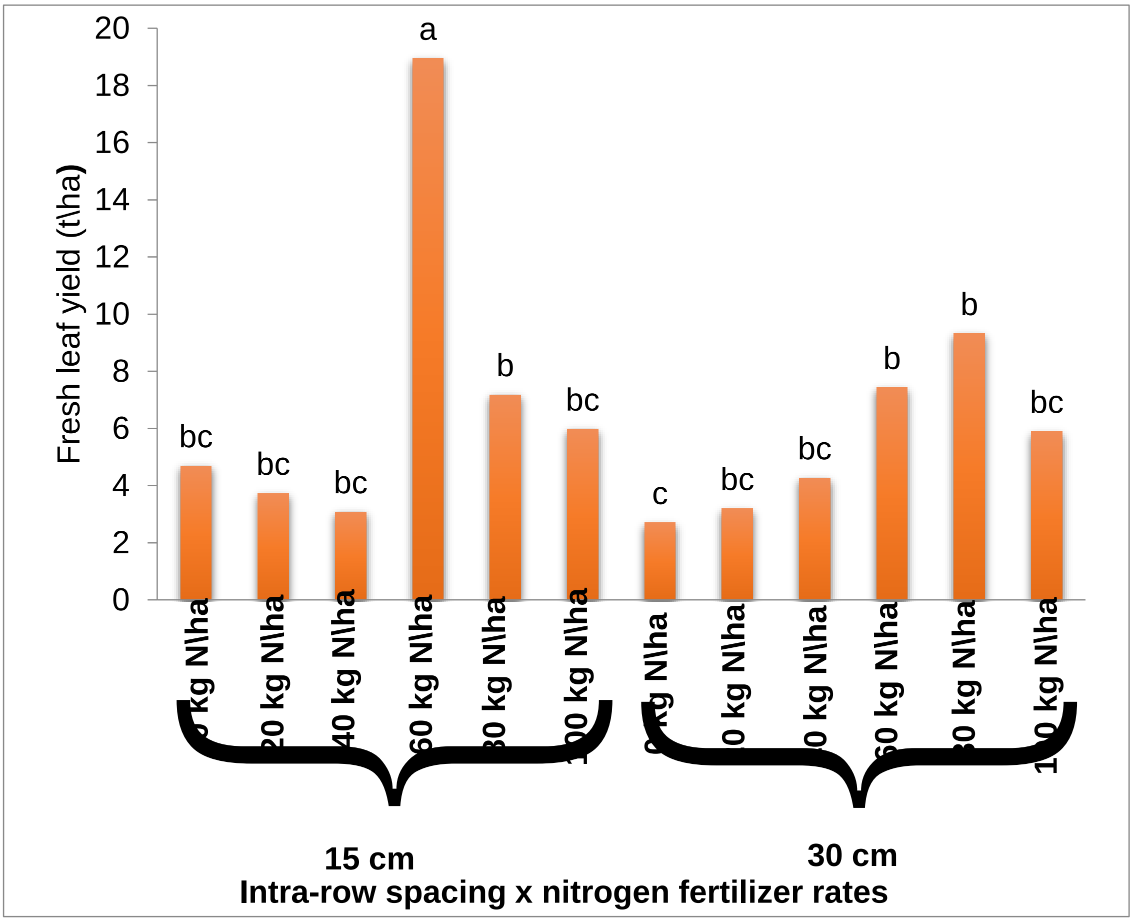
	2014 (April to May)			2015 (March to April, 5 weeks after transplanting)		2015 (April to May, 10 weeks after transplanting)	
Intra-row (cm)	Fertilizer rates (kg/ha)	No of branches	No of leaves	No of branches	No of leaves	No of branches	No of leaves
15	0	4b	76a	6b	42a	4a	37a
	20	5ab	55a	8ab	75a	8a	110a
	40	8a	98a	9ab	124a	8a	74a
	60	7ab	70a	13ab	190a	6a	128a
	80	7ab	67a	7ab	66a	5a	80a
	100	6ab	54a	8ab	118a	6a	61a
30	0	6ab	70a	8ab	116a	7a	51a
	20	8a	89a	9ab	70a	6a	85a
	40	5ab	77a	14ab	98a	7a	91a
	60	5ab	84a	10ab	88a	9a	94a
	80	4b	80a	15a	140a	6a	102a
	100	6ab	66a	11ab	130a	5a	92a
Significance		*	Ns	*	Ns	Ns	Ns
Tukey $HSD_{0.05}$		4	-	8.96	-	-	-

Means in the same column followed by the same letter are not significantly different, HSD=Honest Significant Difference, Ns=non-significant, * significant at P≤0.05.

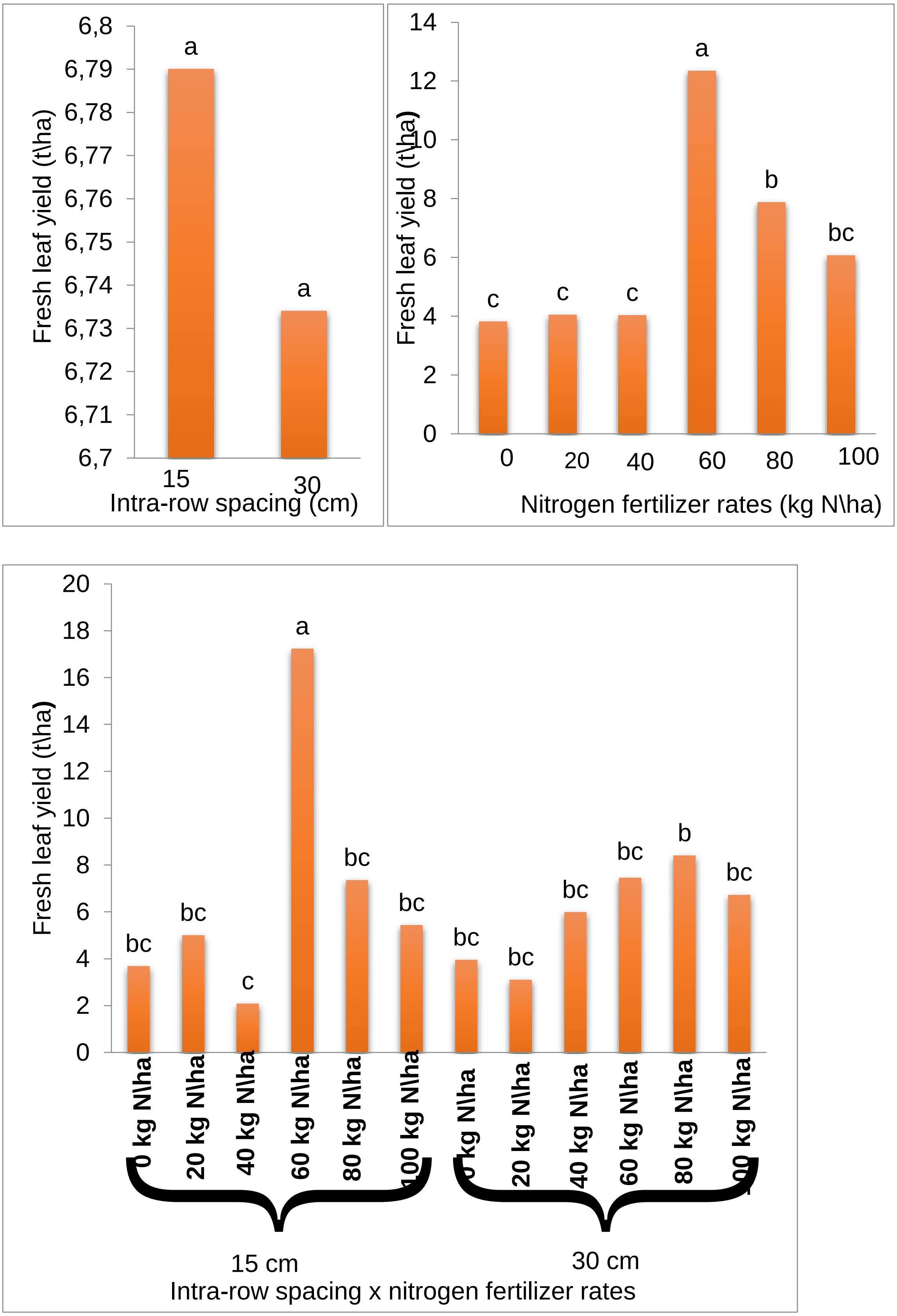
5.3.4 Plant leaf yield produced per hectare in both seasons

A





B*


6,8
6,79
6,78
6,77
6,76
6,75
6,74
6,73
6,72
6,71
6,7
Fresh leaf yield (t\ha)
a
a
15
30
Intra-row spacing (cm)
14
12
10
8
6
4
2
0
Fresh leaf yield (t\ha)
c
c
c
a
b
bc
0
20
40
60
80
100
Nitrogen fertilizer rates (kg N\ha)
20
18
16
14
12
10
8
6
4
2
0
Fresh leaf yield (t\ha)
bc
bc
c
a
bc
bc
bc
bc
bc
bc
b
bc
0 kg N\ha
20 kg N\ha
40 kg N\ha
60 kg N\ha
80 kg N\ha
100 kg N\ha
0 kg N\ha
20 kg N\ha
40 kg N\ha
60 kg N\ha
80 kg N\ha
100 kg N\ha
15 cm
30 cm
Intra-row spacing x nitrogen fertilizer rates

C#

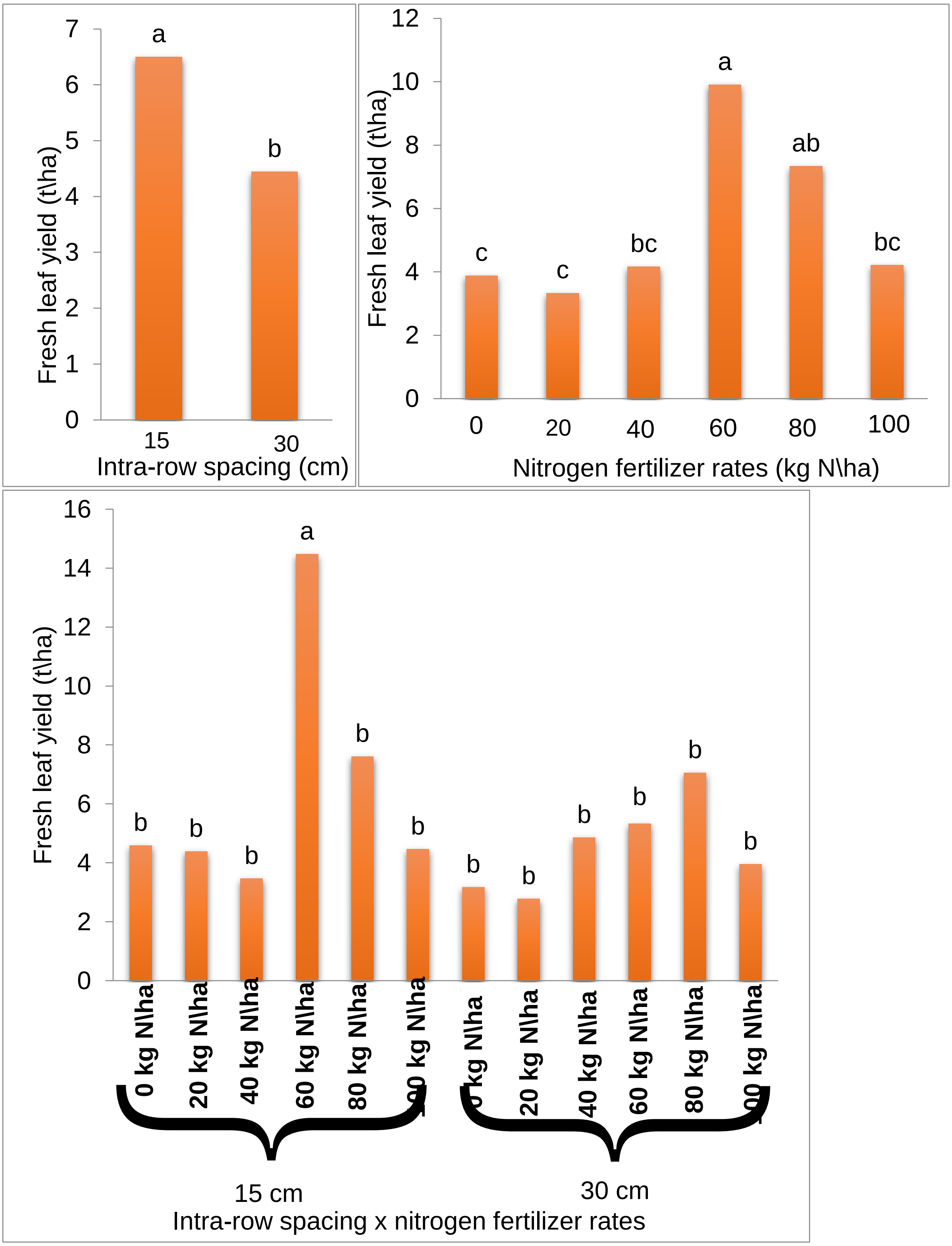


Figure 5.1: Response of intra-row and nitrogen to leaf weight produced in both 2014 and 2015. Bars followed by the same letter are not significantly different at P≤0.05, A= 5 WAT 2014 season, B* = 5 WAT 2015, $C^{\#}$ =10 WAT 2015 season.

Plant leaf yield was significantly influenced by main effects of intra-row spacing and nitrogen fertilizer rate at $P \leq 0.05$ in both seasons (Figure 5.1) except in 2015 season at 5 WAT. For intra-row spacing, 15 cm spacing produced more leaf yield than 30 cm. In 2014 season, 15 cm obtained higher leaf yield by 32.9% compared to 30 cm which obtained the least leaf yield of 5.47 t/ha. In 2015 season at 10 WAT, 15 cm spacing achieved more yield by 28.05% when compared to 30 cm spacing. Plant leaf yield tended to be high with the plants subjected to 60 kg N/ha followed by 80 kg N/ha. Plant leaf yield increased with applied nitrogen fertilizer up to an optimum level followed by decline. From the results it was observed that an increase in nitrogen rate up to 60 kg N/ha increased leaf yield after which there was no further gain in fresh leaf yield. Increase in leaf yield may be due to increases in nutrient availability as the amount of nitrogen applied to the soil is increased. However a sudden decline may occur in higher nitrogen rates could imply that an optimum nitrogen rate is reached for *S. retroflexum* crop production. Sonneveld and Voogt (2009) concluded that crop growth increases as the concentration of nutrients increases until an optimum is reached. Therefore, excess nitrogen may lead to reduced biomass through oxidative damage (Wei *et al*. 2009) or imbalance in nutrient elements.. The results were similar to those reported by Abukutsa-Onyango and Karimi (2005) that leaf yield of African nightshade was significantly ($P \leq 0.05$) affected at 12 weeks after transplanting over two seasons in which there was an increase in growth as nitrogen level increased up to 40 or 80 tonnes per hectare after which there was either no further increase in growth or a decline in growth with further nitrogen level increase. The decline in leaf yield at high nitrogen rates could be explained by the fact that a high concentration of soluble nitrogen increases the osmotic potential of the soil solution, causing reduction in water uptake by the plant roots (Onyango, 2002). Plant leaf yield was also influenced by combined spacing and nitrogen fertilizer rate, with 15 cm x 60 kg N/ha producing more leaf yield than other treatments. In 2014 season, 15 cm x 60 kg N/ha gave a yield of 18.947 t/ha and in 2015 season at 5 and 10 weeks after transplanting, 15 cm x 60 kg N/ha gave yields of 17.22 and 14.47 t/ha, respectively.

5.3.5 Total plant leaf yield produced in 2015 season

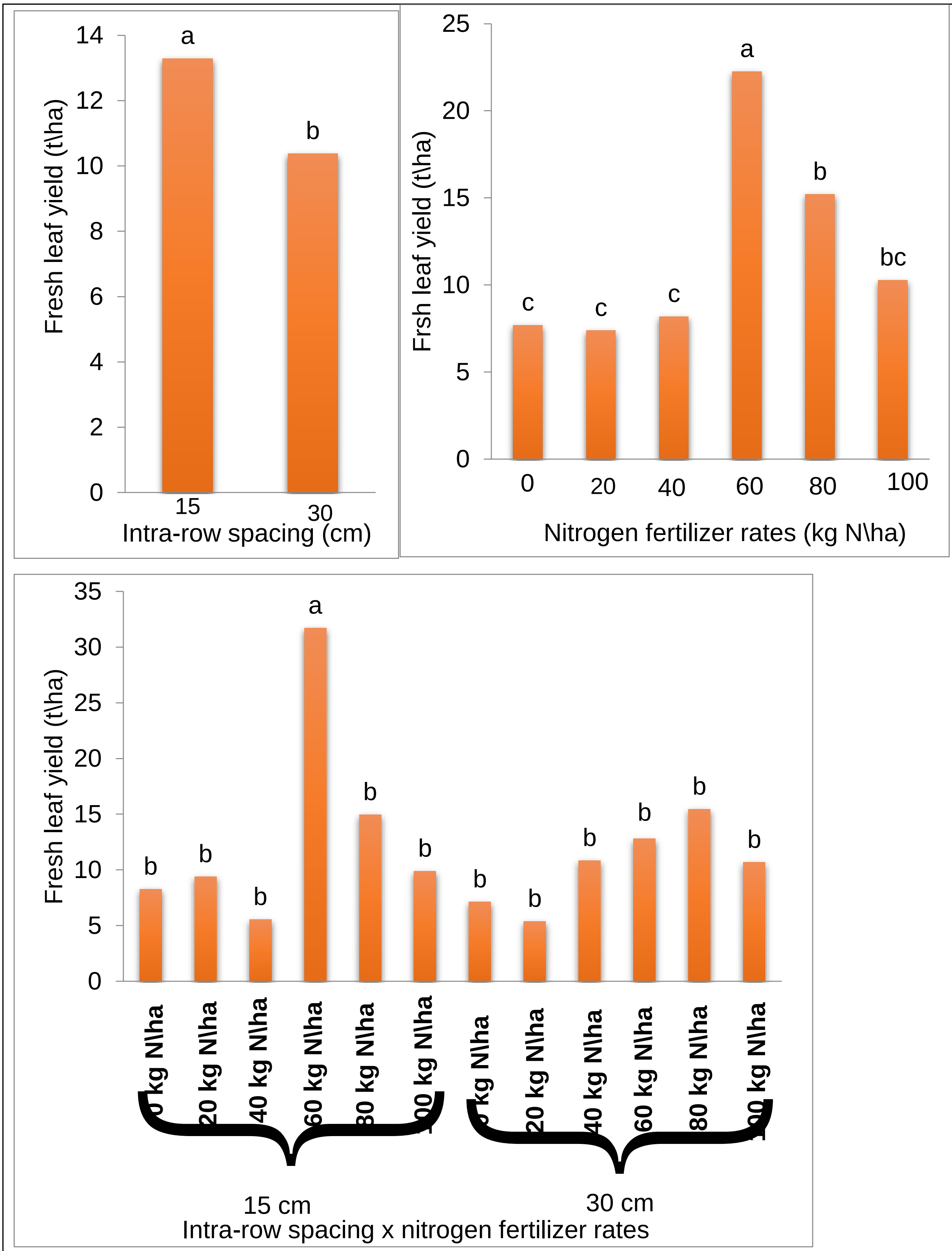


Figure 5.2: Response of spacing to total leaf weight produced in 2015 season. Bars followed by the same letter are not significantly different at P≤0.05

Total leaf yield of 2015 growing season (5 and 10 WAT) was significantly influenced by intra-row spacing at P≤0.05, whereby 15 cm produced more plant leaf yield of 13.29 t/ha than 30 cm that produced a lower total leaf yield of 10.37 t/ha (Figure 5.2). Nitrogen fertilizer rate significantly affected total leaf yield with 60 kg N/ha producing the highest total leaf yield of 22.24 t/ha, followed by 80 kg N/ha which produced 15.20 t/ha. These results followed the same sequence that was found earlier in the study that 60 or 80 kg N/ha produced more leaf yield compared to other rates. From the results, it was observed that the application of nitrogen increases total leaf yield with decline when the optimum rate is exceeded. Similar trends of improved vegetative growth with increasing nitrogen rates have been reported in *S. nigrum* (Murage, 1990). Negative yield responses due to excess nitrogen may be caused by osmotic imbalances due to nitrogen accumulation in plant tissues, which in turn may cause a reduction in the growth and yield of crops (Nkoe *et al.,* 2000). Juma (2006) reported that rate of application of both nitrogen fertilizer and farm yard manure had an influence on the total leaf yield of *S. nigrum*. The application of 150 kg N\ha and 10 t/ha cattle manure produced the highest leaf of 24.7 t/ha. The interaction between the intra-row spacing and nitrogen fertilizer rate significantly (P≤0.05) affected total leaf yield with 15 cm intra-row spacing combined with 60 kg N/ha producing highest total leaf yield of 31.69 t/ha and 30 cm intra-row spacing combined with 20 kg N/ha producing the least total leaf yield of 5.38 t/ha (Figure 5.2).

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The survey study showed that there are about 45 ILVs identified in Limpopo province in the selected districts, of which some were cultivated and some collected from the wild. Cultivation or harvesting of these ILVs was mostly done during rainy seasons in Capricorn and Sekhukhune districts on a small scale whereas in Vhembe district cultivation was done all year round using tractors and irrigation on larger scale. It was also shown that farmers use indigenous knowledge for production of these vegetables therefore, further agronomic studies should be conducted to investigate the correct plant spacing, planting date and harvesting stage, adequate amount of moisture needed by ILVs, optimum fertilizers rates and how to overcome problems of weeds, pests and diseases during production of ILVs. This can be done with the participation of farmers. Improved agronomic production practices can lead to increased yields and improved nutrition and economic empowerment of the rural communities and make it possible for farmers to produce high yields without much costs or management. Indigenous leafy vegetables are known contain high mineral nutrient content that make them able to promote good health. These vegetables were shown to be used to cure some diseases such as high blood pressure, ear infection and wounds. The nutritional profiles of the ILVs show that their consumption should be encouraged for good health. Farmers use these vegetables to generate income; they sell the vegetables to local people but nightshade is also sold in supermarkets in Vhembe district. The major constraints of marketing the vegetable is the abundance of vegetables during the rainy season leading to low prices and scarcity during the dry season when the prices are high. That leads farmers to store dried vegetable to sell during winter when the supply is low and the demand is high. There are some of the ILVs that are preferably consumed in the three districts. Capricorn and Sekhukhune districts pointed out 10 and 12 ILVs as their mostly preferred, respectively, with spider plant being the highest preferred and Vhembe district preferred 9 ILVs with nightshade vegetable being the highest preferred. Even if these vegetables are considered by most of the people, their production is still low due to lack of appropriate agronomic recommendations and limited availability of quality seeds. The two mostly preferred ILVs were also shown to have high market value in their respective districts. There is need for production and supply of quality seed to increase yields and quantities produced to meet the unsatisfied market demands of indigenous vegetables and enhance their consumption. There has been lack of agronomic and preparation packages and access to technical information on ILVs has been very limited. This necessitates research to investigate agronomic practices of ILVs especially for the preferred ILVs in order to maximize yield as they are the ones people utilize most for food security, marketing, cultural purposes as well as medicinal uses. There is a need for follow up studies on domestication of preferred ILVs which are highly limited in natural availability. Related future surveys, resources permitting, should ensure ample sample size.

S. retroflexum is an important indigenous vegetable that ensures food security, alleviates poverty, generates household income and improves human health due to its high nutrient content. Most people from rural areas utilize this vegetable as their source of food as relish. In Limpopo province, marketing of these vegetable is done mostly in Vhembe district by the rural women, who sell these vegetables to local people as street vendors to generate money. It is also sold in supermarkets in that district. Therefore it is vital to know the optimum plant density and fertilizer rates that would maximize nightshade yield.

The study revealed that high plant density is necessary for increasing *S. retroflexum* growth and yield. The results showed that *S. retroflexum* responded positively to closer spacing while wider spacing tended to decrease growth parameters and fresh leaf yield. Inter-row spacings of 30 and 45 cm increased plant height, plant vigour, number of branches, number of leaves and fresh leaf weight together with intra-row spacings of 7.5 and 15 cm. The combination of inter and intra-row spacings of 30 x 7.5 cm was observed as the best for maximum leaf yield.

The second experiment demonstrated the importance of intra-row spacing and nitrogen fertilizer in production of *S. retroflexum* vegetable. Intra-row spacing did not have any significance difference on plant height, number of branches and number of leaves but significantly influenced plant leaf yield, with 15 cm producing the highest yield. Fertilizer application is very crucial in boosting the growth and yield of *S. retroflexum* vegetables. The application of nitrogen fertilizer significantly increased plant height, number of branches and leaves and leaf yield. Our results strongly suggest that the optimum nitrogen level for growth of nightshade is 60 to 80 kg N/ha to have taller plants, many green leaves and enhanced overall fresh leaf yield. Therefore, it is advisable for farmers to use spacing of 30 cm x 15 cm with nitrogen fertilizer rates of 60 kg N/ha to produce maximum leaf yield. These recommendations need to be consolidated with evaluation of their economics.

Because of variability of temperature in Limpopo province, temperature in Vhembe district (warmer) is different to temperatures in Capricorn district (cooler). The optimal temperatures for *S. retroflexum* vary between 15°C and 30°C and the crop is very sensitive to frost. These make it possible for farmers in Tshiombo irrigation scheme to grow *S. retroflexum* all year round. However, at Syferkuil *S. retroflexum* plants were killed by frost before second harvest, that is why early planting was considered as the solution at that site.

REFERENCES

Abukutsa-Onyango, M.O. 2002. Marketing survey on African indigenous vegetables in Western Kenya. In: JM Wesonga, T Lozenge, A Fricke,B Hau and H Stutzel (Eds). Preceedings of the second Horticultural seminar on sustainable Horticultural production in the tropics, Jomo Kenyatta University of Agriculture and Technology, pp. 39-46.

Abukutsa-Onyango, M.O. 2003. Unexploited potential of indigenous African vegetables in Western Kenya. *Maseno Journal of Education Arts and Sciences,* 4(1): pp 103-122.

Abukutsa-Onyango, M.O. and Karimi, K. 2005. Response of broad-leaved African nightshade to nitrogen application. *African Journal of Crop Science Proceedings*, 7: pp.1237-1240.

Adebooye, O.C., Ogbe, F.M.D. and Bamidele, J.F. 2003. Ethno botany of indigenous leaf vegetables of Southwest Nigeria. Delpinoa, University of Naples, Naples, Italy, pp. 45.

Adebooye, O.C. and Opabode, J.T. 2004. Status of conservation of the indigenous leaf vegetables and fruits of Africa*. African Journal of Biotechnology,* 3(120): pp. 700-705.

Adesina, S.K. and Gbile, Z.O. 1984. Steroidal constituents of *Solanum scabrum* subsp. *Nigericum, Fitoterapia,* 55 (6): pp. 362-363.

AVRDC. 2003. *S.scabrum* broad-leaved nightshade. Online: http:/www.avrdc.org.tw. Accessed on 10\06\2016.

Birbal, R.K., Nehra, N. and Malik, S.Y. 1995. Effect of spacing and nitrogen on fruit yield of okra (Abelmoschus esculentus (L.)) cv. Varsha Uphar Haryana*. Agricultural University Journal of Research*, 25, pp. 47-51.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic and available form of phosphorus in soils. *Soil Science,* 59: pp. 39-45*.*

Bromilow, C. 1995. Problem plants of South Africa. Briza Publications, Pretoria, South Africa, pp. 315.

Chweya, J.A. 1997. Genetic enhancement of indigenous vegetables in Kenya. In: Guarino, L., (Ed.), Traditional African Vegetables. International Plant Genetic Resources Institute (IPGRI). Rome, Italy.

Department of Agriculture Forestry and Fisheries (DAFF). 2012. Jew's mallow (*Corchorus olitorius* L.). Department of Agriculture, Forestry and Fisheries, Pretoria.

DAFF. 2013. Black nightshade, *Solanum retroflexum* Dun. Production guidelines. Department of Agriculture Forestry and Fisheries, Pretoria.

Dimri, D. C. and Gulshan, L. 1997. Effect of nitrogen and spacing on leaf nitrogen status and chlorophyll content in tomato (*Lycopersicon esculentus* L) *Annals of Agriculture,* 18 (1), pp. 108-110.

Edmonds, J.M. and Chweya, J.A. 1997. Black nightshades: *Solanum nigrum* L. and related species: promoting the conservation and use of underutilized and neglected crops: International Plant Genetic Resources Institute (IPGRI). Rome, Italy.

Epenhuijsen, C.W. 1974. Growing native vegetables in Nigeria. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 80-88.

Fisher, B. 1977. 'Instant' Fruit — it's Hard to Ask More. *Organic Gardening and Farming,* 24, pp. 74-75.

Food and Agriculture Organization of the United Nations (FAO). 1988. Traditional food plants. *Food and Nutrition*, pp. 42.

Fortuin, F.T.J.M. and Omta, S.W.P. 1980. Growth analysis and shade experiment with *Solanum nigrum* L., the black nightshade, a leaf and a fruit vegetable in West Java. *Netherlands Journal of Agricultural Science,* 28(4), pp. 199-210.

Fox, F.W. and Norwood Young, M.E. 1982. Food from the veld, edible wild plants of South Africa. Delta Book, Johannesburg, South Africa.

Gockowski, J., Mbazo'o, J., Mba, G. and Moulende, T.F. 2003. African traditional leafy vegetables and the urban and peri-urban poor. *Food Policy,* 28(3), pp. 221-235.

Gomez, M.I. 1988. A resource inventory of indigenous and traditional foods in Zimbabwe. *Zambezia,* 15(1), pp. 53-73.

Hart, T.G.B. and Vorster, H.J. 2006. Indigenous Knowledge on the South African Landscape–Potentials for Agricultural Development. Urban, Rural and Economic Development Programme. Occasional paper No 1. HSRC Press, Cape Town, South Africa.

Health benefit of cowpea. 2009. Online: http:/www.fitho.in/guide/beans/cowpeas. Accessed on 21/03/2013

Heever, E. Van Den. and Venter, S.L. 2007. Nutritional and medicinal properties of *Cleome gynandra*. *Acta Horticulturae,* 752, pp. 127-130*.*

Hunter, A.H. 1984. Soil fertility analytical services in Bangladesh. Conultancy Report, BARC, Dhaka, Bangladesh.

IBM SPSS. 2010. IBM SPSS Statistics for Windows version 17.0, United State.

ICRA. 2002. Report from field survey on indigenous leafy vegetables in the Upper East Region of Ghana.

Jansen Van Rensburg, W.S., Venter, S.L., Netshiluvhi, T.R., Van Den Heever, E., Voster, H.J. and J.A. De Ronde. 2007. Role of indigenous leafy vegetables in combating hunger and malnutrition. *Southern African Journal of Botany (*70) 52-59.

Juma, K.A. 2006. Response of *Solanum retroflexum* Dun. to Nitrogen, Phosphorus and Potassium in Pots. M. Tech. (Agric.) Dissertation, Department of Crop Sciences, Tshwane University of Technology, Pretoria, South Africa.

Kamga, R.T., Kouame, C., Atangana, A.R., Chagomoka, T. and Ndango, R. 2013. Nutritional evaluation of five African Indigenous Vegetables. *Journal of Horticultural Research*, 21, pp. 99-106.

Kokwaro, J.O. 1993. Medicinal plants of East Africa, Second Edition, Kenya Literature Bureau. Nairobi, Kenya.

Kokwaro, J.O. 1976. Medicinal plants of East Africa, First Edition, East African Literature Bureau. Nairobi, Kenya.

Kordylas, J.M. 1990. Processing and preservation of tropical and sub-tropical food. McMillan Education Ltd, London, United Kingdom.

Kyeraa, H. 2003. Effect of spacing and weeding frequency on growth and yield of ravaya (*Solanum melongena* cv Baby Aubergine). A BSc dissertation, Department of Horticulture, KNUST, Kumasi.

Lewu, F.B. and Mavengahama, S. 2010. Wild vegetables in northern Kwazulu-Natal, South Africa. Current status of production and research needs, *Scientific Research and Essay*, 5(20), pp. 3044-3048.

Lyatuu, E. and Lebotse, L. 2010. Marketing of indigenous leafy vegetables and how small farmers scale can improve their incomes. Agricultural Research Council Dar es Salaam, Tanzania, pp. 36.

Mackraj, I. 2007. South African plants with a potential for treating high blood pressure. American physiological society meeting: Experimental biology conference Washington DC. <http://www.medscape.com/viewarticle/556658_7.

Manoko, M.L. and Van Der Weerden, G.M. 2004. *Solanum americanum* Mill. [Internet] Record from Protabase. in: Grubben, G.J.H. and Denton, O.A. (eds.): PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale). Wageningen, Netherlands. <http://www.prota.org/search.htm

Mari, J.A., Mondal, L., Fuentes, P., Cristo, M., Martinez, J. and Donate, M. 1997. Effect of transplanting density of the cultivar Yellow Grancx Hybrid on yield and bulb size. *Centro-Agricola* 24 (1): pp. 50- 55.

Mariga, I.K., Lutendo, M. and Maposa, D. 2012. Nutritional assessment of a traditional vegetable (*Brassica oleracea* var. acephala). *Journal of Medicinal Plants Research* volume 6(5), pp. 784-789.

Marshner, H. 1995. Mineral nutrition of higher plants. London, Academic Press, pp 889.

Maundu, P.M., Ngugi, G.W. and Kabuye, C.H.S. 1999. Traditional Food Plants of Kenya. KENRIK National Museums of Kenya, Nairobi, Kenya, pp. 270.

Mavengahama, S. 2013. The contribution of indigenous vegetables to food security and nutrition within selected sites in South Africa. Dissertation presented for the degree of Doctor of Philosophy. Faculty of Agriculture Science, Stellenbosch University. Tygerberg, Cape Town, South Africa.

Maziya-Dixon, B., Akinyele, I.O., Oguntona, E.B., Nokoe, S., Sanusi, R.A. and Harris, E. 2004. Nigeria food Consumption and Nutrition Survey (2001-2003). International Institute for Tropical Agriculture, Ibadan Nigeria.

Mcclintock, N.C. and El-Tahir, I.M. 2004. Production of roselle (*Hibiscus sabdariffa (*L*)*). In: Grubben GJH and Denton OA (edition) Vegetables. Plant Resources Of Tropical Africa, PROTOA Foundation, Backlnnys Publication. Wageningen, Netherlands.

Merinyo, N. 1996. Effect of fertilizer and manure on the yield and harvest duration of black nightshade. In: AVRDC/ARP Training reports. A Compilation of Research Reports by Training Scholars on Vegetable Research and Production. AVRDC, Arusha, Tanzania, pp. 223-225.

Meyer, D.W. 1970. Use of male sterility for increasing the population tolerance of corn (Zea mays L.). Dissertation presented for the degree of Doctor of Philosophy. Lowa State University in Ames, *University Microfilm Order*, 70, pp. 25808.

Mnzava, N.A. 1997. Vegetable crop diversification and the place of traditional species in the tropics. In: Guarino L. (editor), *Traditional African vegetables*. Rome, Italy: International Plant Genetic Resources Institude.

Modi, M., Modi, A. and Hendriks, S. 2006. Potential role for wild vegetables in household food security: a preliminary case study in KwaZulu-Natal, South Africa. *African Journal of Food, Agriculture, Nutrition and Development*, 6(1), pp. 1-7.

Mokwele, M.M. 2009. The production and constraints of nightshade (Muxe) in Vhembe district. Unpublished, BSc Research report, University of Limpopo, Mankweng, South Africa.

Muchiri, S.V. 2004. Characterization and purification of African nightshade *(Solanum nigrum* complex) accessions for sustainable seed production in Kenya.

MSc. Dissertation, Jomo Kenyata University of Agriculture and Technology, Thika, Kenya.

Murage, E.N. 1990. The effect of nitrogen rates on the growth, leaf yield and nutritive quality of the black nightshade *(Solanum nigrum* L.). M.Sc Thesis, University of Nairobi, Nairobi, Kenya.

Murwira, H.K. and Kirchmann, H.1993. Carbon and nitrogen of cattle manures, subjected to different treatments, in Zimbabwean and Swedish Soils. In: Mulongoy, K, Merckx, R (eds) Soil organic matter dynamics and sustainability of tropical agriculture. Wiley-Sayce, Chichester/Exeter, United Kingdom.189-198.

Nguni, D. and Mwild, G. 2007. Opportunities for increased production, utilization and income generation from African leafy vegetables in Zambia. *African Journal for food Agriculture nutrition and Development,* 7, pp. 3.

Nkoe, R., Coulombe, J., Desjardins, Y. and Tremblay, N. 2000. Toward optimisation of growth via nutrient supply phasing: Nitrogen supply phasing increases broccoli (Brassica oleracea var. italica) growth and yield. *Journal of Experimental Botany,* 52, pp. 821-827.

Odhav, B., Beekrumb S., Akulaa U.S. and Baijnath H. 2007. Preliminary assessment of nutritional value of tra- ditional leafy vegetables in KwaZulu-Natal, South Africa. *Journal Food Composition and Analysis,* 2, pp. 430-435.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. 2002. Laboratory Methods of Soil and Plant Analysis: A Working Manual. TSBF-CIAT and Sacred. Africa, Nairobi, Kenya.

Olaniyi, J.O., Adelasoye, K.A. and Jegede, C.O. 2008. Influence of nitrogen fertilizer on the growth, yield and quality of grain amaranth varieties. *World Journal of Agricultural Sciences,* 4, pp. 506-513.

Oliniyi, J.O. and Ajibola, A.T. 2008. Growth and yield performance of *Corchorus olitorius* varieties as affected by nitrogen and phosphorus fertilizers application. *American-Eurasian journal of sustainable* 2: 235-241.

Olaniyi, J.O. 2008. Comparative effects of the source and level of nitrogen on the yield and quality of lettuce. *American-Eurasian Journal of Sustainable Agriculture,* 2(3), pp. 225-228.

Olembo, N.K., Fedha, S.S. and Ngaira, E.S. 1995. Medicinal and Agricultural plants of Ikolomani division of Kakamega District. Signal Press Ltd, Nairobi, Kenya.

Onyango, M.A. 1993. Effect of plant density and harvesting frequency on the yield and Vegetable quality of four variants of black nightshade (*Solanum nigrum* L). MSc thesis. University of Nairobi, Kenya.

Onyango, M.O. 2002. Market Survey on African Indigenous Vegetables in Western Kenya In: Proceedings of the Second Horticulture Seminar on Sustainable Horticultural Production in the tropics, October6th -9th August 2002. Jomo Kenyatta University of Agriculture and Technology,JKUAT, Juja, Kenya. Eds:Wesonga, J.M. T. Losenge, G.K. Ndung'u, K. Ngamau, J.B.M. Njoroge, F.K. Ombwara and S.G. Agong, A. Fricke, B.Hau and H.Stützel. page 39-46.ISBN,9966, pp. 923-27-6.

Onyango, M.O. 2003. Unexploited potential of indigenous African vegetables in Western Kenya. *Maseno Journal of Education, Arts and Science,* 4:103-122.

Prescott-Allen, O.C. and Prescott-Allen, R. 1990. How many plants feed the world? *Conservation Biology*, 4, pp. 365-374.

Ramugumo, L.A. Personal communication, farmer at Tshiombo irrigation scheme.

Roberts, H.A. and Lockett, P.M. 1978. Seed dormancy and field emergence in *Solanum nigrum* L. *Weed Research,* 18, pp. 231-241.

Rizk, F.A. 1997. Productivity of onion plant (*Allium ccpa* L.) as affected by method of planting and NPK application. *Egypt Journal of Horticulture*. 24 (2): pp. 219-228.

Saijo, R., Murakami, K., Nohara, T., Tomimatsa, A., Saito, A. and Matsuoka, K. 1982. Studies on the constituents of Solanum plants II. Constituents of the immature fruits of *Solanum nigrum*. *Yakugaku Zasshi,* 102 (3), pp.300-305.

Schippers, R. 1997. Domestication of Indigenous Vegetables for Sub-Saharan Africa: A Strategy Paper. R. Schippers and Budds, African Indigenous Vegetables, Workshop Proceedings, January 13- 18, 1997, Limbe, Cameroon, pp. 125–135.

Schippers, R.R. 2000. African indigenous vegetables: An overview of the cultivated species. Chatham, UK. Natural Resources Institute /ACP-EU Technical Centre for Agricultural and Rural Cooperation.

Schippers, R.R. 2002. African Indigenous Vegetables: An Overview of the Cultivated Species. Revised edition. [CD-ROM]. Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation, Chatham, Kent, United Kingdom, pp. 252.

Seghatoleslami, M.J., Mousavi, S.G. and Barzgaran, T. 2013. Effect of irrigation and planting date on morpho-physiological traits and yield of roselle (*Hibiscus sabdariffa*). *The Journal of Animal and Plant Sciences,* 23(1), pp. 256.

Shackleton, S.E., Dzerefos, C.M., Shackleton, C.M. and Mathabela, F.R. 1998. Use and trading of wild edible herbs in the central low veld savannah region, South Africa. *Economic Botany*, 52, pp. 251-259.

Shirtliffe, S.J. and Johnston, A.M. 2002. Yield-density relationships and optimum plant populations in two cultivars of solid-seeded dry bean (*Phaseolus vulgaris* L.) grown in Saskatchewan. *Canadian Journal of Plant Science,* 82, pp. 521-529.

Smith, F.I. and Ezyaguirre, P. 2007. African leafy vegetables: Role in World Health Organization‟s Global Fruit and Vegetables Initiative. *African Journal of Food, Agriculture, Nutrition, and Development,* 7(3): pp. 1–17.

Sonneveld, C. and Voogt, W. 2009. Plant nutrition of greenhouse crops. Springer, Dordrecht, The Netherlands.

Spore. 2004. African traditional leafy vegetables and the urban and peri urban poor: In Spore Newsletter, 10: pp. 110.

Thabang, S.S., Moshia, M.E., Shaker, P. and Fouche, P.S. 2013. The impact of in-field spatial variability in uniformly managed small-scale corn (*Zea mays* L.) field. *African Journal of Agricultural Research,* 7(31), pp. 4416-4426.

Thompson, H.C. and Kelly, W.C. 1957. *Vegetable crops*. (5th Edition). New York: McGraw-Hill.

Van Averbeke, W. and Juma, K.A. 2006. The cultivation of Solanum retroflexum Dun. in Vhembe, Limpopo Province, South Africa. Proceeding International Symposium on the Nutritional Value and Water Use of Indigenous Crops for Improved Livelihood:19 – 20 September 2006, University of Pretoria, Pretoria, South Africa.

Van Averbeke, W. and Khosa, T.B. 2004. The Triple-A framework for the analysis of smallholder food commodity chains. In: Proc. 3rd Int. Conf. on Entrepreneurship – Sustainable Globalization. 3-4 November, Pretoria. [CD-ROM]. Tshwane University of Technology, Pretoria, South Africa, pp. 292-299.

Vander Zaag, P., Demagante, A.L. and Ewing, E.E. 1990. Influence of plant spacing on potato (*Solanum tuberosum*) morphology, growth and yiled undertow contrasting environment. *Potato Research*, 33(3), pp. 313-323.

Van Wyk, B. and Gericke, N. 2000. People's Plants. A Guide to Useful Plants of Southern Africa. Briza Publications, Pretoria, South Africa., pp. 352.

Vorster, H.J. 2007. The role and production of traditional leafy vegetables in three rural communities in South Africa, Msc Agric, University of Pretoria, Pretoria, South Africa.

Vorster, H.J. and Jansen Van Rensburg, W.S. 2005. The utilization of traditional leafy vegetables. 6th International Food Data Conference, 14-16 September 2005, University of Pretoria, Pretoria, South Africa. Unpublished. Available from ARC-VOPI, Pretoria, South Africa, pp.12.

Vorster, H.J., Jansen Van Rensburg, W.S., Van Zijl, J.J.B. and Van Den Heever, E. 2002. Germplasm Management of African Leafy Vegetables for the Nutritional and Food Security Needs of Vulnerable Groups in South Africa. Progress Report. ARC-VOPI, Pretoria, South Africa, pp. 130.

Walkley, A. and Black, I.A. 1943. An examination of Degtjareff methods for determing soil organic matter and a proposed modification of the chromic acid titration method. *Soil science*, 37, pp. 29-37.

Weber, L.N. and Van Staden, J .1997. Alternative uses of some invader plants: Turning liabilities into assets. Unpublished. Fort Hare, Eastern Cape, South Africa.

Wehmeyer, A.S. 1966. The nutrient composition of some edible fruits found in the Transvaal. *South African Medical Journal*, 40, pp. 1102-1104.

Wehmeyer, A.S. and Rose, E.F. 1983. Importance of indigenous plants in the Transkei as food supplements. *Bothalia*, 14, pp. 613-615.

Wei, G.P., Yang, L.F., Zhu, Y.L. and Chen, G. 2009. Changes in oxidation damage, antioxidant enzyme activities and polyamine contents in leaves of grafted and non-grafted eggplant seedlings under stress by excess of calcium nitrate. *Science Horticulture*, 120, pp. 443-451.

Whitbread, M.W. 1986. Preliminary Studies on the Utilization and Adaptation of Indigenous and Introduced Vegetable and Grain Amaranths (Amaranthus spp.) in the Natal and KwaZulu Midlands. M.Sc. (Agric) Dissertation. University of Natal, Pietermaritzburg, pp. 54.

Woomer, P.L. and Imbumi, M. 2003. Traditional green vegetables in Kenya. In Organic Resource Management in Kenya- Perspectives and Guidelines, Forum for Organic Resource Management and Agricultural Technologies (FORMAT).

YamaguchI, M. 1983. World vegetables: Principles, production and nutritive values. Van Nostrand Reinhold, New York, USA, pp. 415.

APPENDICES

APPENDIX 1: Survey on utilization of indigenous leafy vegetables (ILVs) found in Limpopo Province

DATE:…………………………

INSTRUCTION: SUPPLY THE CORRECT INFORMATION OR MAKE A CROSS (X) IN THE APPROPRIATE BOX WHERE APPLICABLE

1. Name of the District:…………………………………..
2. Name of the village:……………………………………
3. Name of the respondent:………………………………
4. Gender : Male

   Female

5. Age:………… years
6. Occupation: Self employed

   Government

   Farmer: Livestock

   Plant production

   Both above

7. Size of the family/ household

Number …………….

8. How long have you been staying here?

…………….. Years

Y N

9. Do you have an area in your farm/yard where you grow crops?

10. Which crops do you grow in your farm/yard?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……..

11. Do you grow indigenous leafy vegetables? Y N

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………

12. Which one do you cultivate/domesticate?

13. Which one do they grow naturally in the veld/ garden?

14. What are those that are mostly preferred?

15. The importance of ILVs in term of cultural roles, medicinal use and as a source of food.

Name of ILVs	Utilized as food	Utilized as medicine	Utilized for cultural reasons

16. At what time of the year (season) do you grow these vegetables?

September	October	November	December	January	February

17. How do you prepare the land if you domesticate these vegetables?

By: tractor

Donkeys

Hand hoe

Oxen

Other

18. How do you irrigate your ILVs?

Describe……………………………………………………………………………………………
……………………………………………………………………………………………….

19. Do you use fertilizer during planting? | Y | | N |

If yes, which one and how do you apply it.

…………………………………………………………………………………………………
……………………………………………………………………………………………

20. When do you apply these fertilizer

| Before Planting | | At Planting | | After Planting |

21. Do you use chemicals to manage pests on your vegetables? | Y | | N |

If yes, which chemical, how do you use it and to manage which pest on which crop?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………..

22. Do you use chemicals to manage diseases on your crops? | Y | | N |

If yes, which chemical, how do you use it and to manage which disease on which crop?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………

23. Describe how you harvest your ILVs?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………………………………………….

24. During which part of the year do you mostly consume ILVs?

Name of the ILVs	Time of the year

25. When do you start harvesting your ILVs?

Name	Starting time	Ending time

26. Is it possible to store these vegetables for future use? Y N

If yes, which ones and how.

Vegetable leaves	How

27. What are the ILVs that grow naturally and people would like the most to consume if cultivated?

28. Are there any ILVs sold locally? Y N

If yes, which ones.

29. How do you market your vegetables?

Formal marketing		Informal marketing	

30. At what price do you market your vegetables?

Name	Quantity	Price

31. Has the marketing/demand of ILVs increases or decreases comparing to the previous year?

Describe the cause of this increase or decrease.

Increase	Decrease

APPENDIX 2: Effect of varying plant density on growth and yield of *S. retroflexum* during 2014 (April to May) and 2015 (March to May) growing seasons.

2014 season plant height at 2 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	23.642	11.8211		
Intra-row	3	167.769	55.9230	3.21	0.0427
Inter-row	2	27.362	13.6811	0.79	0.4679
Intra*Inter	6	115.544	19.2574	1.11	0.3900
Error	22	382.811	17.4005		
Total	35	717.129			

2014 season plant height at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	25.620	12.810		
Intra-row	3	403.684	134.561	12.10	0.0001
Inter-row	2	0.247	0.123	0.01	0.9890
Intra*inter	6	103.069	17.178	1.54	0.2105
Error	22	244.700	11.123		
Total	35	777.320			

2014 season plant vigour at 2 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.00002	0.00001		
Intra-row	3	0.09594	0.03198	11.67	0.0001
Inter-row	2	0.00311	0.00155	0.57	0.5756
Intra*Inter	6	0.02307	0.00385	1.40	0.2579
Error	22	0.06031	0.00274		
Total	35	0.18246			

2014 season plant vigour at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.00804	0.00402		
Intra-row	3	0.06433	0.02144	7.62	0.0011
Inter-row	2	0.00347	0.00174	0.62	0.5486
Intra*Inter	6	0.01195	0.00199	0.71	0.6467
Error	22	0.06189	0.00281		
Total	35	0.14969			

2015 season plant height at 2 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	24.056	12.0278		
Intra-row	3	102.049	34.0163	3.90	0.0224
Inter-row	2	21.662	10.8311	1.24	0.3081
Intra*Inter	6	106.338	17.7230	2.03	0.1040
Error	22	191.758	8.7163		
Total	35	445.862			

2015 season plant height at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	85.88	42.9378		
Intra-row	3	84.95	28.3156	0.85	0.4790
Inter-row	2	36.60	18.3011	0.55	0.5832
Intra*Inter	6	118.87	19.8122	0.60	0.7286
Error	22	728.63	33.1196		
Total	35	1054.93			

2015 season plant vigour at 2 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.01238	0.00619		
Intra-row	3	0.07704	0.02568	2.54	0.0823
Inter-row	2	0.02367	0.01184	1.17	0.3282
Intra*Inter	6	0.05870	0.00978	0.97	0.4687
Error	22	0.22211	0.01010		
Total	35	0.39391			

2015 season plant vigour at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.01633	0.08165		
Intra-row	3	0.02652	8.841	3.94	0.0216
Inter-row	2	0.00726	3.628	1.62	0.2209
Intra*Inter	6	0.04666	7.776	3.47	0.0145
Error	22	0.04931	2.241		
Total	35	0.14607			

2015 season plant height at 7 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	39,020	19,51		
Intra-row	3	74,963	24,98	1,66	0,2051
Inter-row	2	2,727	1,363	0,09	0,9139
Intra*Inter	6	95,087	15,847	1,05	0,4202
Error	22	331,593	15,0724		
Total	35	543,390			

2015 season plant height at 10 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	76,08	38,0411		
Intra-row	3	88,73	29,5774	0,83	0,4929
Inter-row	2	41,11	20,5544	0,57	0,5710
Intra*Inter	6	65,50	10,9174	0,31	0,9274
Error	22	786,48	35,7490		
Total	35	1057,91			

2015 season plant vigour at 7 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.00162	0.00081		
Intra-row	3	0.03042	0.01014	1.97	0.1479
Inter-row	2	0.04977	0.02489	4.83	0.0182
Intra*Inter	6	0.01563	0.00260	0.51	0.7971
Error	22	0.11324	0.00515		
Total	35	0.21069			

2015 season plant vigour at 10 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.00016	0.00008		
Intra-row	3	0.05779	0.01926	3.67	0.0277
Inter-row	2	0.09847	0.04924	9.39	0.0011
Intra*Inter	6	0.01733	0.00289	0.55	0.7642
Error	22	0.11538	0.00524		
Total	35	0.28912			

2014 season number of branches

Source	DF	SS	MS	F	P
Replication	2	5.297	2.6483		
Intra-row	3	60.869	20.2896	4.83	0.0099
Inter-row	2	18.333	9.1664	2.18	0.1366
Intra*Inter	6	72.898	12.1497	2.89	0.0311
Error	22	92.403	4.2001		
Total	35	249.799			

2014 season number of leaves

Source	DF	SS	MS	F	P
Replication	2	4467	2233.54		
Intra-row	3	24945	8314.96	2.29	0.1066
Inter-row	2	5111	2555.48	0.70	0.5057
Intra*Inter	6	40256	6709.27	1.85	0.1361
Error	22	79932	3633.25		
Total	35	154710			

2015 season number of branches at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	77.716	38.8578		
Intra-row	3	25.142	8.3807	3.34	0.0380
Inter-row	2	9.662	4.8311	1.92	0.1700
Intra*Inter	6	66.658	11.1096	4.42	0.0044
Error	22	55.271	2.5123		
Total	35	234.449			

2015 season number of leaves at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	7990.9	3995.47		
Intra-row	3	103.3	34.43	0.05	0.9865
Inter-row	2	2086.7	1043.34	1.40	0.2676
Intra*Inter	6	9860.1	1643.35	2.21	0.0812
Error	22	16387.1	744.87		
Total	35	36428.1			

2015 season number of branches at final harvest

Source	DF	SS	MS	F	P
Replication	2	60,722	30,3611		
Intra-row	3	20,750	6,9167	2,33	0,1021
Inter-row	2	1,556	0,7778	0,26	0,7718
Intra*Inter	6	12,667	2,1111	0,71	0,6441
Error	22	65,278	2,9672		
Total	35	160,972			

2015 season number of leaves final harvest

Source	DF	SS	MS	F	P
Replication	2	5686,2	2843,11		
Intra-row	3	5048,3	1682,77	1,71	0,1932
Inter-row	2	4478,4	2239,19	2,28	0,1258
Intra*Inter	6	3962,9	660,49	0,67	0,6726
Error	22	21591,8	981,44		
Total	35	40767,6			

2014 season fresh leaf yield 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	51,65	25,827		
Intra-row	3	2140,08	713,361	24,58	0,0000
Inter-row	2	124,69	62,343	2,15	0,1406
Intra*Inter	6	2134,49	355,748	12,26	0,0000
Error	22	638,53	29,024		
Total	35	5089,44			

2015 season fresh leaf yield 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	118,24	59,119		
Intra-row	3	811,45	270,484	6,65	0,0023
Inter-row	2	234,35	117,177	2,88	0,0775
Intra*Inter	6	1988,39	331,398	8,14	0,0001
Error	22	895,22	40,692		
Total	35	4047,65			

2015 season fresh leaf yield final harvest

Source	DF	SS	MS	F	P
Replication	2	0,645	0,3227		
Inter-row	2	145,679	72,8396	34,35	0,0000
Intra-row	3	283,786	94,5955	44,61	0,0000
Inter*Intra	6	78,538	13,0897	6,17	0,0007
Error	22	46,656	2,1207		
Total	35	555,305			

2015 season total leaf yield of 5 weeks after transplanting and final harvest

Source	DF	SS	MS	F	P
Replication	2	0.33	0.164		
Inter-row	2	1139.76	379.921	36.79	0,0000
Intra-row	3	535.62	267.809	25.93	0,0000
Inter*Intra	6	326.50	54.416	5.27	0,0017
Error	22	227.19	10.327		
Total	35	2229.40			

APPENDIX 3: Effect of nitrogen fertilizer rate and plant density on growth and yield of *S. retroflexum* during 2014 (April to May) and 2015 (March to May) growing seasons.

2014 season plant height at 2 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	75.129	37.5644		
Intra-row	1	5.760	5.7600	0.50	0.4889
Nitrogen	5	37.636	7.5271	0.65	0.6663
Intra*Nitrogen	5	68.880	13.7760	1.18	0.3484
Error	22	255.778	11.6263		
Total	35	443.182			

2014 season plant height at harvest period

Source	DF	SS	MS	F	P
Replication	2	189.140	94.5700		
Intra-row	1	21.468	21.4678	1.88	0.1841
Nitrogen	5	22.090	4.4180	0.39	0.8523
Intra*Nitrogen	5	102.552	20.5104	1.80	0.1551
Error	22	251.100	11.4136		
Total	35	586.350			

2014 season plant vigour at 2 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.08927	0.04463		
Intra-row	1	0.03121	0.03121	13.66	0.0013
Nitrogen	5	0.00773	0.00155	0.68	0.6454
Intra*Nitrogen	5	0.03322	0.00664	2.91	0.0366
Error	22	0.05027	0.00228		
Total	35	0.21170			

2014 season plant vigour at harvest period

Source	DF	SS	MS	F	P
Replication	2	0.08315	0.04158		
Intra-row	1	0.04134	0.04134	14.95	0.0008
Nitrogen	5	0.00250	0.00050	0.18	0.9669
Intra*Nitrogen	5	0.01676	0.00335	1.21	0.3366
Error	22	0.06085	0.00277		
Total	35	0.20460			

<u>2015 season plant height at 2 weeks after transplanting</u>

Source	DF	SS	MS	F	P
Replication	2	224.87	112.435		
Intra-row	1	152,11	152,111	6,31	0,0191
Nitrogen	5	995,56	199,111	8,26	0,0001
Intra*Nitrogen	5	95,22	19,044	0,79	0,5673
Error	22	578,67	24,111		
Total	35	2046.43			

<u>2015 season plant height at 5 weeks after transplanting</u>

Source	DF	SS	MS	F	P
Replication	2	341.74	170.87		
Intra-row	1	2,37	2,366	0,02	0,8767
Nitrogen	5	763,33	152,666	1,59	0,2020
Intra*Nitrogen	5	196,43	39,286	0,41	0,8384
Error	22	2310,39	96,266		
Total	35	3614.25			

<u>2015 season plant vigour at 2 weeks after transplanting</u>

Source	DF	SS	MS	F	P
Replication	2	6.4	3.2		
Intra-row	1	0,00840	0,00840	1,23	0,2782
Nitrogen	5	0,09045	0,01809	2,65	0,0481
Intra*Nitrogen	5	0,04591	0,00918	1,35	0,2795
Error	22	0,16380	0,00683		
Total	35	6,70856			

2015 season plant vigour at 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.01446	0.0723		
Intra-row	1	0,00723	0,00723	0,93	0,3446
Nitrogen	5	0,21732	0,04346	5,59	0,0015
Intra*Nitrogen	5	0,02139	0,00428	0,55	0,7364
Error	22	0,18653	0,00777		
Total	35	0,44693			

2015 season plant height at 7 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	178.51	89.254		
Nitrogen	5	1604.16	320.832	4.17	0.0081
Intra-row	1	16.23	16.227	0.21	0.6505
Nitrogen*Intra	341.11	68.222	0.89	0.5064	
Error	22	1691.90	76.905		
Total	35	3831.91			

2015 season plant height at 10 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	138.39	69.196		
Nitrogen	5	2186.47	437.293	3.96	0.0103
Intra-row	1	15.69	15.695	0.14	0.7097
Nitrogen*Intra	5	784.14	156.827	1.42	0.2557
Error	22	2427.73	110.351		
Total	35	5552.41			

2015 season plant vigour at 7 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.07801	0.03900		
Nitrogen	5	0.01931	3.863	0.76	0.5853
Intra-row	1	2.77806	2.778	0.00	0.9815
Nitrogen*Intra	5	0.09178	0.01836	3.63	0.0151
Error	22	0.11119	5.05403		
Total	35	0.30030			

2015 season plant vigour at 10 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	0.06104	0.03052		
Nitrogen	5	0.05769	0.01154	4.59	0.0051
Intra-row	1	0.01000	0.01000	3.98	0.0586
Nitrogen*Intra	5	0.08497	0.01699	6.76	0.0006
Error	22	0.05529	0.00251		
Total	35	0.26899			

2014 season number of branches

Source	DF	SS	MS	F	P
Replication	2	20.162	10.0811		
Intra-row	1	2.007	2.0069	1.15	0.2955
Nitrogen	5	16.371	3.2743	1.87	0.1401
Intra*Nitrogen	5	54.998	10.9996	6.29	0.0009
Error	22	38.444	1.7475		
Total	35	131.983			

2014 season number of leaves

Source	DF	SS	MS	F	P
Replication	2	8012.2	4006.09		
Intra-row	1	531.3	531.30	1.30	0.2660
Nitrogen	5	2296.6	459.33	1.13	0.3758
Intra*Nitrogen	5	2688.1	537.61	1.32	0.2929
Error	22	8973.5	407.89		
Total	35	22501.7			

2015 season number of branches 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	118	59		
Intra-row	1	56,250	56,2500	6,06	0,0214
Nitrogen	5	103,917	20,7833	2,24	0,0831
Intra*Nitrogen	5	105,917	21,1833	2,28	0,0784
Error	22	222,667	9,2778		
Total	35	606.75			

2015 season number of leaves 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	1257	628.5		
Intra-row	1	348,7	348,69	0,72	0,4054
Nitrogen	5	8007,9	1601,58	3,29	0,0209
Intra*Nitrogen	5	9399,3	1879,86	3,87	0,0103
Error	22	11665,7	486,07		
Total	35	30678.5			

2015 season number of branches final harvest

Source	DF	SS	MS	F	P
Replication	2	23.722	11.8611		
Nitrogen	5	35.222	7.0444	1.93	0.1299
Intra-row	1	2.778	2.7778	0.76	0.3924
Nitrogen*Intra	5	24.222	4.8444	1.33	0.2893
Error	22	80.278	3.6490		
Total	35	166.222			

2015 season number of leaves final harvest

Source	DF	SS	MS	F	P
Replication	2	507.6	253.78		
Nitrogen	5	15875.2	3175.04	2.01	0.1166
Intra-row	1	144.0	144.00	0.09	0.7654
Nitrogen*Intra	5	5284.0	1056.80	0.67	0.6506
Error	22	34719.1	1578.14		
Total	35	56529.9			

2014 season fresh leaf yield final harvest

Source	DF	SS	MS	F	P
Replication	2	10,251	5,1257		
Intra-row	1	25,931	25,9312	5,85	0,0243
Nitrogen	5	389,746	77,9492	17,58	0,0000
Intra*Nitrogen	5	154,551	30,9101	6,97	0,0005
Error	22	97,538	4,4336		
Total	35				

2015 season fresh leaf yield 5 weeks after transplanting

Source	DF	SS	MS	F	P
Replication	2	26,027	13,0137		
Intra-row	1	66,536	66,5357	11,94	0,0023
Nitrogen	5	38,201	7,6401	1,37	0,2733
Intra*Nitrogen	5	14,894	2,9788	0,53	0,7480
Error	22	122,633	5,5742		
Total	35	268,291			

2015 season fresh leaf yield final harvest

Source	DF	SS	MS	F	P
Replication	2	2905922	1452961		
Intra-row	1	2,31308	2,31308	245,08	0,0000
Nitrogen	5	9341306	1868261	1,98	0,1217
Intra*Nitrogen	5	7918684	1583737	1,68	0,1818
Error	22	2,07707	943916		
Total	35	2,72308			

2015 season total leaf yield of 5 weeks after transplanting and final harvest

Source	DF	SS	MS	F	P
Replication	2	44,454	22,227		
Intra-row	1	546,005	546,005	104,67	0,0000
Nitrogen	5	73,933	14,787	2,83	0,0401
Intra*Nitrogen	5	30,576	6,115	1,17	0,3541
Error	22	114,757	5,216		
Total	35	809,723			