Chemotaxonomic Study on the Genus

*Ziziphus* Tourn. ex L. in the Sudan

By

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Dedication

To the soul of my father,

to my dear mother,

to my dear husband,

to my dear brothers and sisters.
Acknowledgement

I would like to express my appreciation and gratitude to my supervisor Dr. Abdel Gabar, N. Gumaa (Faculty of Education) U of K. for his assistance, critical comments and constant interest throughout the course of this work.

My thanks are extended to my husband Mohamed Ahmed for his moral and financial support.

I would also like to thank my family for their patience and encouragement, especially my sister Isra who took care and looked after my son during the course of this work Mohammed A/Gabbar for assisting in the typing of this manuscript.
Abstract

Name: Nuha Mohammed El Hassan Satti

Title: Chemotaxonomic Study on the genus Ziziphus Tourn. ex L. in the Sudan

This research is composed of two parts:

a taxonomic and a chemical study on the genus Ziziphus in the Sudan.

The objectives of this study were: identification, classification and documentation of the species of the genus Ziziphus in the Sudan, determination of the major chemical components of the fruits of the genus, construction of taxonomic keys based on morphology and chemical components of fruits and the survey of the various uses of the genus in the Sudanese rural areas.

Plant materials were collected from different parts of the Sudan, with special reference to the states of Gezira, Kordofan, Darfur and the White Nile. The collected plants were identified and synonymy was updated.

Brief botanical species descriptions have been given with notes on geographical distribution and common uses. The species were photographed by digital camera.

Fruits were chemically analyzed according to the methods adopted by the A.O.A.C. (1965; 1984). These methods were used for the determination of the following contents: moisture, ash, crude protein, fat, crude fiber, carbohydrates, reducing sugars, sucrose and the elements Ca, Mg, Fe, and P.

High performance liquid chromatography (HPLC) was used for the determination of citric and ascorbic acid contents. Results of chemical data were analyzed using the variance ratio test (F-test) with a probability of 5%.
The major findings of this study were:

- Five *Ziziphus* spp. were identified, namely: *Z.spina-christi*, *Z.abyssinica*, *Z.mauritiana*, *Z.mucronata* and *Z.pubescens*.

- *Ziziphus* spp. are multipurpose and have many uses such as food, medicine, rituals and often superstitions.

- The fruit provides good famine food at times of food scarcity.

- *Ziziphus* spp. occur even in arid or semi-arid regions, and are thus considered as drought-resistant plants.

Results of statistical analysis of chemical data showed that:

- There are significant differences among the *Ziziphus* spp. in their chemical components.

- There are significant differences among the chemical components of *Z.mauritiana*, on one hand, and those of *Z.spina-christi* and *Z.abyssinica* on the other hand.

This study recommends the following:

- Propagation and domestication of *Ziziphus* spp. in all arid and semi-arid areas of the Sudan.

- Introduction of *Ziziphus* spp. in food security and desertification programs in the Sudan.

- Development of packaging and preservation methods of *Z.mauritiana* fruits exported to some Arab countries.
The study concerns the class of Ziziphus in Sudan. It aims at:

- Characterizing and classifying the species and discussing their utilization Ziziphus in Sudan.

The study also mentions: Classification of the species, determination of the main areas of occurrence and utilization in Ziziphus with the help of the scientific bodies concerned.

- Description of the main areas of occurrence and the types of diseases and deficiencies in the regions of the Sudanian savannah, and the neighboring areas.

- Chemical analysis of the food and medicinal substances using HPLC and other chemical methods.

- The study concludes that Ziziphus species in Sudan are rich in food and medicinal substances.

Keywords: Z.mucronata, ÜZ.mauritiana, ÜZ.abyssinica, ÜZ.spina-christi, Z.pubescens

XIII
• فرقوتاً معنوية توجد جنس أنواع بين Ziziphus الكيميائية الحيوية حيث.

• فرقوتاً معنوية توجد الكيميائية الحيوية بين Z.mauritiana ونوعي Z.spina-christi وZ.abyssinica أخرى، جهة من.

بالتالي الدراسة هذه توصي -:

• جنس أنواع وتطويز زراعة Ziziphus الجافة وشبه الجافة المناطق ككل في السودان.

• جنس أنواع ودخول Ziziphus الغذاء الأمين في في التشحر ومواجهة في السودان.

• نوع ثمار وحفظ تعبئة طريق تطور Z.mauritiana الدول للبعض التي العربية.
CHAPTER 1

1-1 Introduction

Out of the 7000 cultivated plant species worldwide (Raman, 2006), food security has become increasingly dependent on a small number of crops (Borlaug, 2002). Nevertheless, an extrapolation, by FAO (1999) indicates that a number of 18,000 – 25,000 wild-collected species are used as food. Among those, indigenous fruit trees play a very important role in the livelihood of rural people, especially for those living in dry areas (Von Maydell, 1989), where crop failure often results in poor nutrition of the local population (Maxwell, 1991). Although such plants are considered as neglected or underutilized at the global level, they are often known to have important uses at the local or national agriculture and food procurement systems and are important genetic resources in global efforts to maintain biodiversity (Grivetti and Ogle, 2000). In many parts of Sudan, wild plant genetic resources are common in the normal diet, but are especially important during famine periods (Gebauer et al., 2002; Robison, 2005). However, their potentialities are neither exploited nor fully appreciated and their contribution to farmers livelihoods is not sufficiently acknowledged in poverty reduction strategies (Schreckenberg et al., 2006), in spite of the obvious interest of local people in such indigenous plants for food, additional income generation, livestock feed, folk medicine, energy, and for their role in soil conservation such as the stabilization of sanddunes (Gebauer et al., 2007a).

To meet the needs of an increasing world population, the development of alternative crops to improve the range of commodities available is needed (EL-Siddig et al., 1999). This is particularly important
for crops which can withstand harsh conditions such as drought, heat and salinity stress (Gebauer, 2005).

Jujubes are species of the genus *Ziziphus* Tourn. ex L. which belongs to the family Rhamnaceae, named after the genus *Rhamnus*. The name *Ziziphus* is related to an Arabic word (zizoufo) used along the North African coast for *Z. lotus* (L.), Desf., but also related to the ancient Persian words *zizfum* or *zizafun* while ancient Greeks used the word *ziziphon* for the jujube.

There are two major domesticated jujubes: *Z.mauritiana* Lam. and *Z. jujube* Mill. These two species have been cultivated over vast areas of the old world. A limited number of other species have been, and are, cultivated on a more localized scale, (NAS , 1980; Adams et al., 1978). At about the same time an assessment of species for expanded use in the sahelian regions noted the multipurpose value of jujube species including food, honey production, forage and environmental protection (Von Maydell, 1986).

Sudan, as in many other African countries, is endowed with a range of edapho-climatic conditions that favor the establishment of many plant species, most of which are adapted to specific ecologival zones. Among these plants are *Ziziphus spina- christi*, *Z.abyssinica* and *Z.mauritiana*, locally known as Nabag or Nabak. These are found to grow in central Sudan and the states of Kordofan, Darfur, Blue Nile. Some of these plants are prevalent at various areas of the Sudan (Gebauer et al., 2002).

*Ziziphus* is an important fruit species. The fleshy drupes of several *Ziziphus* species are rich in sugar and vitamins, and this fact has made *Ziziphus* spp. important fruit trees for many centuries. *Ziziphus* trees have a long tradition of selection and cultivation (Cherry, 1985).

The fruits of all *Ziziphus* spp. are edible and can be prepared for consumption in many ways. The drupes are eaten either fresh, pickled,
dried or made into confectionary, and the juice can be made into a refreshing drink (Facciola, 1990).

*Ziziphus spina-christi* is used for the treatment of ulcers, wounds, eye diseases and bronchitis. Plant leaves are also used in medicine as an antiseptic, antifungal and anti-inflammatory agent, and for healing skin diseases such as dermatitis (El Ghazali et al., 1994). It has been described as ant cathartic, astringent, diuretic and tonic (Duke, 1985; Bal., 1992). Fruits were found to have a very high energy value. They can be eaten raw or dried for later use and have pleasant sub-acid taste, somewhat resembling dried apples (Facciola, 1990). The seeds were rich in protein and the leaves in calcium, iron and magnesium. Fruits are laxative and have been used as a vermifuge and a remedy for high blood pressure (Levy, 1991). In western Sudan, ripe fruits are fermented and prepared into a confection or eaten. In Kordofan and Darfur, fruits are used as a delicacy. The bitter–sweet pulp of fruit is dried and milled to produce a fine flour (Abdelmuti, 1991).

*Ziziphus abyssinica* is found in wooded grassland and along rivers. Its cream pulp and outer skin are eaten. The pulp has a sweet to slightly bitter taste but the edible portion is small. It is used for construction, as firewood, fodder, charcoal production, medicine, forage and fences (Chikamai et al., 2004).

Extracts of the fruit of *Z. abyssinica* were screened for phytochemical, antimicrobial, antioxidant and toxic activity, with the overall objective of determining its potential to preserve meat products (Baratta et al., 1998). Fruits of *Z. mauritiana* have higher contents of protein and vitamin C than apples (Anonymous, 1992). Fruits are eaten raw or cooked (Chittendon, 1992).

*Ziziphus* fruits are very nutritious and are usually eaten fresh. The leaves are used as nutritious fodder for sheep and goats (Kaaria, 1998).
Ripe fruit has a sweet and sour taste which can expel phlegm, relieve cough and can also be used as a laxative. Samros jujube is popular to consume fresh but due to the excess productivity and little consumption, it is processed in chips, paste, candy and preserved food (Li et al., 2007).

1.2 Objectives of the study:

1. To identify the species of the genus *Ziziphus* in the Sudan.
2. To determine the chemical components of the fruits of the Sudanese species of the genus *Ziziphus*.
3. To construct taxonomic keys for the *Ziziphus* spp. based on their morphology and chemical components of their fruits.
4. To document the common folkloric uses of the genus *Ziziphus* in the Sudan.
CHAPTER 2

Literature Review

Ziziphus is a multipurpose genus that has a wide range of uses, which includes nutritional, medicinal and other folkloric uses. The genus has also a wide range of distribution. Here is an elaborate literature review of the uses of the main Ziziphus spp and their distribution.

2.1 The Taxonomy of the genus Ziziphus Tourn. ex L.

Members of the genus Ziziphus, commonly referred to as jujubes, belong to family Rhamnaceae. The name Ziziphus is related to the Arabic word zizoufo which was used for Z. lotus (L.) Desf. along the North African coast. It is also related to the Persian words zizfum or zizfun. Ancient Greeks used the word ziziphon for the jujube (Williams, 1998).

There are two major domesticated jujubes namely: Z. mauritiana Lam., which is commonly known as the Indian jujube or ber and Z. jujuba Mill. which is commonly known as the Chinese or common jujube.

The national Academy of Sciences (NAS) (1980) reported that Z. spina-christi (L.) Desf. is used for firwood. In arid and semi-arid zones. NAS (1980) and Adams et al. (1978) noted the multipurpose value of jujube species including food, honey production, forage and environmental protection. India had already included Z. mauritiana in its national program on underutilized crops.

Most earlier divisions of the genus were based on characteristics of the inflorescence (Sussenguth, 1953). However, Liu and Cheng (1995) considered that the details of inflorescence types are unstable and suggested the division of the genus into two sections:
1. **Ziziphus**: Here the plants are glabrous and have deciduous fruiting branchlets.

2. **Perdurans**: Here the plants are pilose and have no deciduous fruiting branchlets.

### 2.1.1 The species of the genus:

There is a consensus that the genus contains about (135 species) (Bhansali, 1975) while Liu and Cheng (1995) suggested that there could be up to 70 species. The variation in the number of species depends on the taxonomist’s view of the species. However, it was found that many of the species have been reduced to synonyms.

The genus *Ziziphus* has a complex taxonomy because the same specific name has been used by different authors for different species even in published papers. For example, *Z. mauritiana* Lam. had the specific name *Z. jujuba* (L.) Lam. and *Z. jujuba* (L.) Gaertn. (Williams, 1998). Similarly *Z. abyssinica* A. Rich. had been called *Z. jujuba* Hems. There are numerous examples as this one such as the synonyms *Z. rotundifolia* and *Z. nummularia*.

Reasons for the complexity of the taxonomy of this genus are its wide geographical distribution and hybridization.

### 2.2 Uses of the genus *Ziziphus*

#### 2.2.1 *Z. spina-christi* (L.) Desf.

**Uses as food:**

Fruits of *Z. spina-christi* are used as food especially for people in western and central Sudan and other Saharian regions. Fruits are collected by women and children and sold in local markets. This provides an
additional source of income for local people, who may use the revenue to buy important non-food items. Similarly, in Oman fruits are collected from wild and cultivated plants and sold in local markets (Gebauer et al., 2007b). Fruits are consumed either fresh or dried and the sweet pulp of the fruit is dried to product fine flour. The dried pulp flour and water are also mixed with sesame and formed into small balls for immediate use (Zakaria et al., 2000). In western Sudan, fruits are fermented and prepared into a confection and ripe fruit is eaten raw (Abdelmuti, 1991). In Oman fruits, including kernels, are ground to produce an edible mealy substance which is either eaten raw or cooked in water, milk or buttermilk (Miller and Morris, 1988).

The leaves provide valuable animal forage and fodder under open grazing conditions (Verinumbe, 1993). This is especially important during the dry season when grazing is limited. Small branches are often cropped as dry season fodder for camels and goats and later used to make thorn fences (Bunderson et al., 1990; Maydell, 1986).

2.2.2 Medicinal Uses:

Most of the rural people in Sudan have no access to modern medicine and rely heavily on traditional cures, mostly prepared from plant (Robinson, 2006). The genus *Ziziphus* is known for its medicinal properties as a hypoglycemic, hypotensive, anti-inflammatory, antimicrobial, antioxidant, antitumour and liver protective agent and as an immune system stimulant (Said et al., 2006). In central Sudan, fruits of *Z. spina-christi*, Christ’s fruits, are eaten to treat diarrhea and malaria and as an antispasmodic. The powder of the twigs is used externally to treat rheumatism and scorpion sting (El Kamali and El Khalifa, 1999).
In northern Kordofan state the poultice of the powdered leaves is used to heal swellings and macerated roots are used as an antipurgative (El Ghazali et al., 1997). In the White Nile State, the decoctions of the bark are used to treat intestinal spasms (El Ghazali et al., 1994; El Ghazali et al., 1997). In the Sahel region, the roots are reported as a treatment against headaches, while spines and ashes are applied to heal snake bites. Boiled leaves are applied to various surface wounds and against diarrhea (Anonymous, 1992).

Other uses:

The honey collected from the flowers of Z.spina-christi is of excellent flavor (Sudhersan and Hussain, 2003). The wood is used as source of fuel and it produces an excellent charcoal. The timber is used for tool handles, fence posts, bedstead legs, walking sticks, furniture, bent wood chairs, roofing beams, doors, windows and turned items. It is hard and heavy and is known to resist termites (Sudhersan and Hussain, 2003). For Muslims seeds are used as rosaries, while for Christians the thorns are reported to have made up the crown of thorns of Jesus. In natural religions, the roots are used in superstitious practices (Bircher and Bircher, 2000).

Distribution

The genus Ziziphus is known to be drought and very resistant to heat (Paroda and Mal, 1989). It can be found in desert areas with very low rainfall(Jawanda and Bal, 1992). Z.spina-christi is found over the whole Sahelian area from Senegal to Sudan and across a large area in North Africa, Middle East, Afghanistan and North West India (Maydell,
1986; Arbonnier, 2004). The species is native to Sudan (El Amin, 1990; Vogt, 1995; Dafni et al., 2005).

The species can tolerate high temperatures. It grows in desert areas with an annual rainfall of 50-300mm (Maydell, 1986), but is often also found in wadis where underground water is available (Boulos, 2000).

In Sudan the tree is found in the central Sudan, Kordofan, Darfur, Blue Nile and Bahr Elghazal. However, a good tree growth is found in southern Kordofan. (El Amin, 1990).
2.2.2 *Z.abyssinica*A.Rich.

**Uses as food:**

Meat is one of the most nutritional but also most perishable foods. Unless it is preserved or stored under cool conditions, it rapidly deteriorates and becomes either unfit or unsafe for human consumption (Mureithi, 1996). Lack of scientific knowledge has often constituted a major constraint to the use of traditional herbal remedies in conjunction with or as affordable alternatives to conventional preservatives (Bein, 1996).

The pulp has sweet to slightly bitter taste but the edible portion is small (Chikamai et al., 2004). The sweet fruits are edible, and the leaves may be cooked as vegetable (Orwa et al., 2009). Fruit is used to make porridge and meal (Ben et al., 2000). Seeds can be roasted as a coffee substitute (Orwa et al., 2009).

Animals like giraffes are known to be especially fond of the leaves of this tree. Leaves are eaten by giraffe, antelope, cattle, and goats. Fruit is eaten by small antelope, baboons, and monkeys. Fruits and leaves are high in nutritional value although not very palatable. They are eagerly eaten by antelope, monkeys, baboons, and especially birds (Roodt, 1998).

*Z.abyssinica* rootstocks can be used to produce ten food products (Nerd and Mizrahi, 1998).

**Medicinal Uses:**

A concoction of the bark and the leaves is used for respiratory ailment and other septic swellings of the skin (Palmer and Pitman, 1982). Ash from the burnt leaves is mixed with salt and applied on the throat to relieve tonsillitis (Bein, 1996).
Fresh leaves are chewed and applied directly to wounds, boils and sores to reduce pain and inflammation and promote healing (Ben et al., 2000). In east Africa, roots are used for treating snake bites (Hutchings et al., 1996). A fermentation of steaming hot leaves soaked in boiling water are applied on the chest to treat pneumonia (Bein, 1996). A paste of the leaves is used to treat boils and glandular swellings (Ben et al., 2000). The flour, prepared from the pulp mixed with water, is an excellent thirst-quencher (Roodt, 1998).

The root bark is used as an ametic, febrifuge and laxative. The root is used for diarrhea, dysentery, oral treatments, pain-killer, stomach troubles and venereal diseases (Bein, 1996). The seed is used in phytochemistry for the preparation of fatty acids (Bein, 1996).

**Other Uses:**

Tree is used for construction, as firewood or fodder (Chikamai et al., 2004). The apiculture *Ziziphus abyssinica* is an excellent tree for bees since both pollen and nectar are easily available (Katende et al., 1995). This species is a source of firewood and is used in the production of charcoal (Chikamai et al., 2004). The dark brown to black wood is heavy, hard and resistant to termites and borers (Bein, 1996). Thus, it is used mainly as poles to fence Kraals and villages and to cover graves and is also used for furniture, interior work and carving (Beentje, 1994).

**Distribution**

*Z. abyssinica* is found growing in arid or dry tropical and subtropical regions, with severe heat and slight frost. It occurs at medium to low altitudes, in open woodland, open grassland and along riverbanks; it reaches its southernmost limit along the southern boundaries of Zambia valley. The tree grows throughout Zambia accept for 5 districts in the northwest corner and is widespread outside Zambia from Senegal and
Ethiopia south to Angola and Mozambique. It grows throughout East Africa. In Uganda, it occurs in Savannah (Orwa et al., 2009).

It grows in south Sudan, Kenya and Tanzania (Sommerlatte, 1990).

In Sudan the tree is found in central, Kordofan, Darfur and Blue Nile (Al Amin, 1990).

2.2.3 Z. mauritiana Lam.

Uses as food:

Fruits are very nutritious and are usually eaten fresh (Karia, 1998; Adzu et al., 2001) This fruit is a rich source of vitamin C (Von Maydell, 1989).

Ripe fruit has sweet taste (Li et al., 2007). The fruit can be eaten fresh, dried like dates or cooked in puddings, cakes, breads, jellies, soups (Facciola, 1990). Fruits are often left to become wrinkled and spongy, which increases their sweetness, and are then eaten fresh or cooked (Bown, 1995). The dried powder is used in the preparation of kochujangy, a fermented hot pepper–soybean paste that resembles miso (Facciola, 1990). In India, the ripe fruits are mostly consumed raw, but are sometimes stewed. Slightly under-ripe fruits are candied by a process of pricking, immersing in a salt solution gradually raised from 2 to 8%, draining, immersing in another solution of 8% salt and 0.2% potassium metabisulphite, storing for 1 to 3 months, rinsing and cooking in sugar syrup with citric acid. Ripe fruits are also crushed in water forming a very popular cold drink (Morton, 1987).

In part of India and north Africa, the leaves are used as nutritious fodder for sheep and goats (Gupta, 1993).
**Medicinal uses:**

A jujube is both a delicious fruit and an effective herbal. It aids weight gain, improves muscular strength and increases stamina (Chevallier, 1996). In Chinese medicine, it is prescribed as a tonic to strengthen liver function (Chevallier et al., 1996). Japanese research has shown that jujube increases immune-system resistance. In one clinical trial in China, 12 patients with liver complaints were given jujube, peanuts and brown sugar. In four weeks it was observed that their liver function had improved (Chevallier et al., 1996). Jujubes are considered to purify the blood and aid digestion (Chopra, 1986). They are used internally in the treatment of a range of conditions including chronic fatigue, loss of appetite, diarrhea, pharyngitis, bronchitis, anemia, irritability and hysteria (Yeung, 1985; Bown, 1995). A decoction of the root has been used in the treatment of fevers (Grieve, 1984; Chopra, 1986). The root is made into a powder and applied to old wounds and ulcers (Chopra, 1986). The leaves are a stringent and febrifuge (Grieve, 1984, Duke, 1985). They are said to promote the growth of hair (Duke, 1985). They are used to from a plaster in the treatment of skin diseases (Chopra, 1986). The plant is a folk remedy for anemia, hypertension, nephritis and nervous diseases (Duke, 1985). It is also used as a treatment for burns (Duke, 1985). The leaves are applied as poultices and are helpful in liver troubles, asthma and fever (Michel, 2002).

**Other Uses:**

Fruit in sub-saharan Africa contributes to household income (Tembo et al., 2008a).

The foregoing literature review on the uses of the genus *Ziziphus* reveals that plant materials are cheap and significantly contribute to the improvement of human health in terms of cure and prevention of diseases
Plants have been useful as food and medicine and a few have been studied especially Africa medicinal plants (Ogle et al., 2003; Adebooye and Opabode, 2004, Ayodele, 2005). They contain vitamins needed by human body for healthy living (Szeto et al., 2002; Jimoh et al., 2008).

**Distribution**

Indian jujube is native from the province of Yunnan in Southern China to Afghanistan, Malaysia and Queensland, Australia. It is cultivated to some extent throughout its natural range (Morton, 1987). It grows in north Africa and north India. However, ber is now widely distributed and has become naturalized in tropical areas, Iran, Syria, Burma and parts of the Mediterranean (Von Maydell, 1986).

**2.3 Chemical components of Ziziphus spp.**

**2.3.1 Total carbohydrates:**

Data cited in literature indicated that *Ziziphus spina-christi* fruit pulp contains various amounts of total carbohydrates as follows: 80.9% (Duke, 1985), 81.6% (Nour et al., 1987) 81.6% (Abdelmuti, 1991), 63.1% (Eden, 1992) and 80.7% (Getachew, 2001). Nour et al. (1987), Abdelgalil and Eljissry (1991) and Abdelmuti (1991) reported that the total sugar contents of *Z.spinachristi* were 47.5%, 47.5%, 47.5%, 21.8%, respectively while those of sucrose were 21.8%, 21.8%, 21.8%, respectively. *Ziziphus abyssinica* fruits contains 86% total carbohydrates (Benhura and Katayi. Chidewe, 2000).

*Ziziphus mauritiana* fruits contains total carbohydrates as follows: 12.8% (Singh et al., 1967), 13.9% (Jawanda et al 1981), 12.8% (Von Maydell, 1986), 2.4% (Morton, 1987), and 8.8% (Li et al., 2007).
According to Morton (1987), Von May dell, (1980), Chovatia et al.(1993) and Pareek, (2001), the total sugar values in Z.mauritiana fruit pulp were 21.6%, 20 – 30%, 10.8%, 9.6 – 3%, respectively. The reducing sugar values were: 1.4% - 6.2% (Morton, 1987), 5.1% (Chovatia et al., (1993)), and 5.6% (Bal, 1992).

2.3.2 Fiber:

According to Nour et al (1987) Berry-Koch (1990), Abdegalil and Eljissry (1991), Abdelmuti (1991) and Getachew (2001) the Z.spina-christi fruit pulp fiber contents were 5.3%, 4.1%, 4.1% , 4.1 and 4.7% respectively.

Ziziphus abyssinica fruits pulp fiber content was found to be 2.6% (Russel, 1947). Z.mauritiana fruit pulp fiber was found to be 4% (Duke, 1985) , 1.28% , (Morton, 1987) 3.4% (Grosskinsky, 1998) and 2.8%, (Li et al., 2007).

2.3.3 Ash:

The ash content of Ziziphus spina-christi fruit pulp were studied by Duke (1985), Nour et al. (1987), Abdelgalil et al(1991), Abdelmuti (1991) and Getachew (2001). They reported values of 4.4%, 3.5%, 4.4%%, 4.4% and 7.2% respectively. Russel (1947) and (Benhura and Katayi – Chidewe(2000)) found that Z. abyssinica fruit contains 3.7% and 0.7% ash, respectively.

Parmar (1982), Duke (1985), Morton (1987), Grosskinsky, (1998) and (Li et al., 2007) found that the ash content of Z.mauritiana were 1.4% , 3% , 3% , 2.8% and 1.1% ash, respectively.

2.3.4 Moisture content:

The moisture content of Z.spina-christi fruit pulp, as reported by different researchers, were as follows: 9.3% (Duke,1985), 6% (Nour et al., 1987) and 7.6%, (Getachew, 2001). Z.abyssinica fruit moisture was
6.00% (Boynes, 1940), 9.2% (Russel, 1947) and 9.1% (Benhura and Katayi - Chidewe, 2000).

*Z.mauritiana* fruits moisture contents were 81% (Bal, 1992), 81% (Pareek, 2001), 81.6 – 83% (Morton, 1987) and 87% (Li *et al.*, 2007).

**2.3.5 Fats:**

The fat content of *Z.spina-christi* fruit pulp was studied by many authors (Duke, 1985; Nour *et al.*, 1987; Berry-Koch *et al.*, 1990; Abdelgalil and Eljissry, 1991; Abdelmuti, 1991; Eden, 1992; Sirvastava and Kumar, 1998; Getachew, 2001). They found values of 0.9%, 0.8%, 0.9%, 2.1%, 1.1, 2.2% and 1.1%, respectively.

The fat content of *Z. abyssinica* fruits was found to be 0.5% (Boynes, 1940), 1.4% (Russel, 1947) and 0.2% (Babayemi, 2007). The fat contents of *Z. mauritiana* were 1.2% (Duke, 1985), 0.2% (Morton, 1987), 0.1% (Grosskinsky, 1998), and 0.3% (Li *et al.*, 2007).

**2.3.6 Proteins:**

The protein contents of *Z. spina-christi* fruit pulp were found to be 4.8% (Duke, 1985), 3.6% (Nour *et al.*, 1987) 4.8 – 5.6% (Abdelgalil and Eljssry, 1991), 2.8% (Abdelmuti, 1991) 3.1% (Eden, 1992) and 3.2% (Getachewo, 2001). *Z.abyssinica* fruit protein content was found to be 9.8% (Russel, 1947), 1.4% (Rittner and Reel, 1992) and 2.6% (Benhura and Katayi – Chidewe, 2000). *Z.mauritiana* protein contents were found to be 2.6% (Parmar, 1982) 7.3% (Duke, 1985), 2.5% (Von Maydell, 1986) 2.9% (Pareek, 2001) and 1.05% (Li *et al.*, 2007).
2.4 Mineral Composition:

2.4.1 Ca content:
The Ca content of *Z.spina-christi* fruit pulp were studied by Duke (1985), Nour *et al*. (1987), Berry-Koch (1990), Abdelgalil and Eljissry. (1991), Abdelmuti (1991) and Eden (1992) who reported values of 1.4%, 1.02%, 1.4%, 0.6%, 0.61% and 1.7%, respectively.

*Z.mauritiana* Ca content were studied by Duke (1985), Morton (1987) and Grosskinsky, (1998) who found values of 1.3%, 2.5% and 2.1%, respectively.

2.4.2 Mg content:
This was studied by Abdelgalil and Eljissry.(1991), Abdelmuti(1991) and Eden (1992) who found Mg contents of 0.12%, 0.10% and 0.56, respectively for *Z.spina-christi*.

Mg content of *Z.mauritiana* was found to be 0.3% by Grosskinsky (1998).

2.4.3 Fe content:
The Fe content of *Z.spina-christi* was studied by Duke (1985), Berry-koch(1990), Abdelgalil and Eljissry,(1991) and Eden(1992). They reported values of 0.03%, 0.02%, 0.03% and 0.06%, respectively.

The Fe content of *Z.mauritiana* was 0.016% (Duke, 1985), 0.026% (Morton 1987), and 0.56% (Grosskinsky, 1998).

2.4.4 P content:
P content of *Z.spina christi* was found to be 1.06% (Nour *et al*., 1987), 1.3% (Eden, 1992) and 1.6% (Duke, 1985).
P content of *Z.abyssinica* was studied by Russel(1947) who found a value of 0.2%.
P content of *Z.muritiana* was reported as follows: 0.16% (Duke ,1985), 0.25% (Morton, 1987) and 0.056% (Grosskinsky ,1998).
2.5 **Organic acids:**

Organic acids are important constituents which influence flavor, brightness of colour, stability and quality of food. The titrable fraction of fruit tissues content of organic acids varies from 0.2 – 0.3%, in low-acid apples and bananas, to 2.00% in logan berries and over 6.00% in lemon (Leo, 1992). Citric acid may constitute up to 6.00% of the total solids of the edible portion of the lemon. Organic acids reduce the sweetness and increase the tartness of food in which they occur and in this way influence palatability. The sour taste of acid is influenced more by total acidity than pH. The acids improve the palatability of many products and contributes to the maintenance of acid-base balance in the body. They also act as chelating agents for iron and copper and inhibit enzymes.

Organic acids are characterized by their carboxyl (COOH) group which dissociates into a proton and a conjugate base and thus endows the organic acids with their acid properties. The acid properties of other food compounds arise from other functional groups such as the two enol groups of ascorbic acids (Leo, 1992).

Organic acids can be classified according to the type of carbon chain (aliphatic, alicyclic, aromatic and heterocyclic) and the extent of unsaturation and substitution. The lowest mono-carboxylic aliphatic acids (with 1-4 carbon atoms) are pungent, rather volatile liquids, while those with five or more carbon atoms are aleaginous, slightly water-soluble liquids. Di-carboxylic acids are colorless crystalline solids with melting points about 100°C. On the other hand, alicyclic acids which contain at least one non benzene cyclic hydrocarbon skeleton, are less soluble metal salts and esters. All organic acids occur naturally in a variety of vegetable and animal substrates (Leo, 1992).
2.5.1 Ascorbic acid:

The ascorbic acid content (mg/100g) of *Z.spina-christi* was found to be 30mg (Abdelglil and Eljissry, 1991), 30mg (Abdelmuti, 1991) 24mg (Grosskinsky, 1998) and 35mg (Getachwo, 2001). *Z.mauritiana* fruit pulp is a good source of vitamins and is considered to be a rich source of vitamin C. The vitamin C content range is 70 – 165mg (Bal and Mann, 1978). Duke (1985), Morton (1987) and Grosskinsky, (1998) reported values of ascorbic acid in fruit pulp of *Z.mauritiana* as 30mg, 66 – 76mg and 24mg, respectively. *Z. mauritiana* fruit is richer than apple in vitamin C (Bakhshi et al., 1972).

2.5.2 Citric acid:

The citric acid content of *Z.mauritiana* fruit pulp was found to be 0.2 – 1.1 mg by Morton (1987).
CHAPTER 3

Material & Methods

3.1 Field and herbarium Methods:

The plant material was collected from Wadrawah (Central Sudan), Darfur (Western Sudan) and Kordofan (Western Sudan), during the period December 2008 to March 2009.

A preliminary identification of the collected plant material was made using Andrews (1952). The identification was later checked using EL Amin, (1990), El Awad (1995), Mohamed (1992), Williams (1998) and Sahni (1968). The identification was then confirmed by comparison with identified herbarium material from the herbaria of: Faculty of Science, U. of K., Medicinal and Aromatic Plant Research Institute (MAPRI), Khartoum and Forest Research Center at Soba, Khartoum.

Brief descriptions have been provided for the family as well as the identified species of the genus Ziziphus.

Notes on distribution have been provided for each of the identified species.

Taxonomic keys have been constructed for the identified species based on morphological characters.

3.2. Preparation of fruit pulps and coats:

The fruit pulps and coats of the identified Ziziphus species were removed and the seeds were then manually separated from the pulp. All samples were milled, mixed, packaged in polyethylene bags and kept in a freezer.
3.3 Determination of moisture content:

The moisture content of each sample was determined according to A.O.A.C. (1984), as follows:
Samples of about 10, 10 and 67-77 g. were taken from the fruit pulps of each of *Z. spina-christi*, *Z. abyssinica* and *Z. mauritiana* respectively.
Each sample was put in a pre-heated crucible of known weight and then dried at 107°C for overnight.
The crucible was then transferred to a dessicator, allowed to cool to room temperature and was then reweighed.
The moisture content of each sample was calculated according to the following equation:

\[
\text{Moisture} \% = \frac{A - B}{\text{Weight of sample}} \times 100
\]

Where:

\[A = \text{weight of crucible + sample (before drying)}\]
\[B = \text{weight of crucible + sample (after drying)}\]

3.4 Determination of ash content:

The total ash of *Ziziphus* samples was estimated according to A.O.A.C. (1984). Ten g of *Ziziphus spina-christi*, 5 g of *Z. abyssinica* and (6-9) g of *Z. mauritiana* were each heated in a crucible in a muffle furnace at 550°C for 3 hours. The crucible was then cooled in a dessicator and reweighed at room temperature. The ash content of each sample was calculated using the following equation:

\[
\text{Ash content} \% = \frac{W_1 - W_2}{W_3} \times 100
\]

Where:

\[W_1 = \text{weight of crucible (g) + ash}\]
\[W_2 = \text{weight of empty crucible (g)}\]
\[W_3 = \text{weight of sample (g)}\]
3.5 Determination of crude protein:

The crude protein was determined by the semi-micro-kjeldahl method described by Pearson (1976). 0.2 g. of the sample were weighed in a semi-microdigestion flask. One g. of the catalyst (sodium sulphate + cupric sulphate 20:1 by weight) and 10 ml of concentrated sulphuric acid were added and the content was heated till a clear solution was obtained. The solution was transferred to the distillation unit and the flask was rinsed with distilled water. The mixture was steam-distilled in a receiver containing 10 ml of 20% boric acid and a few drops of mixed indicator (ethylene blue and methyl red). The distillate was titrated against 0.2 N hydrochloric acid. The total nitrogen percentage was determined by the following equation:

\[
\text{Total nitrogen} \% = \frac{V \times N \times 14}{w \times 1000} \times 100
\]

Where:

- \(V\) = volume (ml) of hydrochloric acid.
- \(N\) = normality of hydrochloric acid.
- \(w\) = weight of original sample (g.).

The crude protein was determined from the total nitrogen by the following equation:

\[
\text{Crude protein} = 6.25 \times \text{total nitrogen}
\]

3.6 Fat content:

The fat content of *Ziziphus* spp. was determined according to the method of Pearson (1970), by extracting the dry sample with petroleum ether at 60 – 80°C in a continuous Soxhlet extraction apparatus. Five g. of dry sample were accurately weighed in an empty thimble and plugged with a piece of cotton wool. The thimble and the dry material
were then placed in a Soxhlet extractor. A dry Soxhlet flask was accurately weighed ($W_1$) and then fitted to the extractor. Petroleum ether was added in until the flask was approximately two-thirds filled. The solution was heated by an electric heater and extracted for 6 - 8 hours. The extract was evaporated to dryness in an air oven overnight at $100{^\circ}C$. The flask was cooled in a dessicator and reweighed ($W_2$). The fat percentage was calculated as follows:

\[
\text{Fat content \%} = \frac{W_1 - W_2}{\text{weight of sample}} \times 100
\]

3.7 Crude fiber:

The crude fiber content of *Ziziphus* spp. was determined according to A.O.A.C. (1965). Two g of the sample were accurately weighed, transferred to an extraction apparatus and extracted with petroleum spirit. The air-dried fat-free sample was then transferred to a dry 750 ml beaker and 200 ml of boiling 1.25% (0.255 N) sulphuric acid were added. The mixture was boiled for 30 minutes, and the contents of the beaker were filtered through Whatman No.1 filter paper in a Buchner funnel. The residue was washed 3-4 times with 50-75 ml boiling distilled water. Suction was applied to dry the residue in the Buchner funnel. The residue was transferred to a beaker and 200 ml of 1.25% boiling sodium hydroxide were added and the contents were boiled. The residue was dried for 2 hours at $130{^\circ}C$ and ignited in a muffle furnace at $550{^\circ}C$ to constant weight.

The percentage of crude fiber was determined by the following equation:

\[
\text{Crude fiber \%} = \frac{S}{W_1 - W_2} \times 100
\]

**Where:**

$W_1$ = weight of dry residue before ignition.

$W_2$ = weight of residue after ignition (ash).

S = original weight of sample.
3.8 Total carbohydrates:

Total carbohydrates were determined by Pomeran and Meloan (1992) and calculated as percent by the following equation:

Carbohydrates % = 100 – (CP%+CF%+FC%+Ash%+ MC%)

Where:

CP = Crude protein
CF = Crude fiber
FC = Fat content
MC = Moisture content

3.9. Sugar Determinations:

i. Reducing sugars:

Reducing sugars of *Ziziphus* spp, were determined by the modified Schneier method described by the I.C.U.M.S.A (1979). A 20 g. sample of the material was extracted with ethanol (75%) for 6 hours in a Soxhlet apparatus and the extract was evaporated to 100 ml.

The solution was clarified by a mixture of 2ml lead acetate and 3 ml sodium oxalate solution. In a concial flask, 10 ml of Fehling solution (Fehling A and B) were pipetted and about 15 ml of the sugar solution were run in from a burette. The mixture was heated to boiling, and the sugar solution was then added drop by drop. The flask was shaken until the colour changed to a rich green solution and methylene blue was then added. The end point of the titration was when the solution changed colour to red.

Reducing sugars were calculated from the Lane-Egyon table according to the following equation:

Reducing sugars % = \( \frac{\text{mg of sugar}}{100 \text{ ml of solution}} \times \text{dilution} \times 100 \)

\( \frac{1000 \times \text{weight of sample (g)}}{1000} \)
ii. Total sugars:

The total sugar content of *Ziziphus* spp. was determined by the modified Schneier method described by the I.C.U.M.S.A. (1979). Ten ml of dilute HCl (1:1) was added to 50 ml of the sugar solution and left to stand for overnight. The solution was neutralized by NaOH (40%) using phenolphthalene, as an indicator. The procedure was repeated and the total sugars were calculated, as in the reducting sugars, from the invert sugar table.

iii. Determination of sucrose:

Sucrose content of *Ziziphus* spp. was determined by the I.C.U.M.S.A (1979) and calculated from the Lane-Egyon table according to the following equation:

\[ \text{Sucrose \%} = \text{total sugars \%} - \text{reducing sugars \%} \]

3.10. Determination of mineral elements:

**Preparation of plant samples for elemental analysis:**

Plant samples were prepared according to the method described by Chapman and Prett (1961). One g. of fruit pulp was weighed in a clean dry crucible. The crucible was placed in a muffle furnace (550°C) for 2 hours. The contents of the crucible were cooled and 10 ml of 5N-HCl were added. The crucible was heated in a hot sand bath for about 10 – 15 min and the contents were then filtered into a volumetric flask (100 ml) and the solution was then made to volume.

**Determination of iron, calcium, magnesium and phosphorus:**

These were determined according to the method described by Stewart (1989), using an atomic absorption spectrophotometer (Perkin Elmer, model 2330). Different concentrations of standards were used.
The cation percentage was calculated as follows:

\[
\text{Cation\%} = \frac{\text{Reading (ppm) } \times \text{ dilution factor}}{\text{Sample weight (g)}} \times 100
\]

3.11 Determination of organic acids (ascorbic acid and citric acid):

The organic acids content was determined by the High-Performance Liquid Chromatography (HPLC) according to the method described by Marsil et al. (1981).

HPLC (Hewlett pacierd 1050) ultraviolet/ visible detector column laypersil ODS sum (4.0 × 250 mm) was used.

Regents:

Acentonitrile / water (15:25 / V: UL were used as mobile phase).

Analytical grade organic acids were used as standards. Grade acetonitrile was used in sample preparation.

Procedure:

Five g of samples were weighed and 0.5ml distilled water and 20 ml acetonitrile were added and transferred to a 50 ml glass centrifuge tube. The tube was shaken for 1 min, and centrifuged at 7000 × G for 5 min. The supernatant was injected into the 10 UL loop with 5 ml syringe fitted with swinney syringe filter holder containing 0.2 UM Teflon membrane filters.

Complete duplicate analyses were performed on all samples to enable calculation of average deviations which were useful as a measure of extraction and chromatographic reproducibility. Initially, aqueous standards of individual acids were chromatographed separately to determine the retention times of each acid. Samples of aqueous acids were then chromatographed. The acid percentage was calculated in two steps.

\[
i- \quad C_1 = \frac{C_2 \times Ar_1}{Ar_2}
\]
ii- Acid % = \(\frac{C_1 \times 100}{W}\)

Where:

- \(C_1\) = conc. of sample.
- \(C_2\) = conc. of standard.
- \(A_{r1}\) = Area of sample.
- \(A_{r2}\) = Area of standard
- \(W\) = weight of sample.

3.11 Statistical analysis of chemical data.

Chemical data were analyzed using the variance ratio test (F-test) with a probability of 5% (P=.05).
CHAPTER 4

Results and Discussion

4.1 Botanical Studies:-

Members of the genus *Ziziphus*, commonly referred to as jujubes, belong to family Rhamnaceae. The name *Ziziphus* is related to the Arabic word zizoufo which was used for *Z. lotus* (L.) Desf. along the North African coast. It is also related to the Persian words zizfum or zizfun. Ancient Greeks used the word ziziphon for the jujube (Williams, 1998).

In this study, 5 *Ziziphus* spp. were identified namely: *Z.spina-christi*, *Z.abyssinica*, *Z.mauritiana*, *Z.mucronata* and *Z.pubescens*.

*Ziziphus* Tourn. ex L.

**Key to the species (based on morphology)**

A. Unarmed trees or shrubs; bark rough; leaves elliptic or oblanceolate – elliptic, pubescent; fruit ellipsoid, yellow or red – yellow, up to 1cm across. ……………………*Z.pubescens*

AA. Armed trees or shrubs; bark scaly or deeply furrowed or deeply fissured; leaves mostly ovate or obovate or lanceolate, usually glabrous; fruit globose or spherical, reddish or reddish brown, more than 1cm across:

B. Bark deeply furrowed; leaf – base asymmetrical; flowers with sharp unpleasant smell; fruit spherical, shiny red. ……………………………………………………………..*Z.abyssinica.*

BB. Bark scaly or deeply fissured; leaf – base symmetrical; flowers not as above; fruit globose, reddish or reddish – brown:

C. Bark scaly; sepals wooly above; fruit pulp astringent to taste. ……………………………………………………………..*Z.spina-christi*.
Bark deeply fissured; sepals not as above; fruit pulp sweet – acidic or bitter:

D. Bark reddish or greyish – brown; fruit sweet – acidic, edible. .............................................................. Z. mauritiana.

DD. Bark dark – grey; fruit bitter, unedible. .............................................................. Z. mucronata

The following is a brief outline for each of the identified Ziziphus spp. in this study.

1. Z. spina-christi (L.) Desf.


Vernacular names:

Common English name: Christ's thorn
Common Arabic names: Nabaj, Nabak or Nabag (fruit)  
                        Sidr (tree).

Botanical description:

Shrubs or small trees, 10 – 15 m tall; branches often interwining; young branchlets not densely white pubescent; fruiting branchlets not deciduous; bark deeply furrowed and scaly, white brown to pale-grey; stipular spines 2, unequal in length, one straight and the other recurved. Leaves ovate-lanceolate or ovate-elliptic, usually 2-8x 2-3 cm, margin crenulate, base rounded, more or less symmetrical, apex obtuse, glabrous at maturity; petiole usually 10 – 15 mm long. Inflorescence short auxiliary cymes; sepals woolly above. Fruits subglobose to globose drupes, yellow, reddish or red-brown, usually 2x1 cm; fruit pulp astringent to taste. Flowering period: July – October.
fruiting period: August – December.

This species has two varieties:

1. *var. spina-christi* (L.). Desf.
   Shrub or small trees, 10 – 15 m tall; leaves ovate- lanceolate or ovate-elliptic. Fruit 2x1 cm.

2. *var. microphylla* A. Rich.
   Shrubs, 4-5 m; leaves elliptic. Fruit about 1 cm long and often forms impenetrable thickets.

**Distribution.**

The tree is found in central Sudan, Kordofan, Darfur, Eastern Sudan, Blue Nile, Bahr Elghazal and Upper Nile. However, a good tree growth is found in southern Kordofan.

**Common Uses:**

Fruits are used as food especially by people in western and central Sudan. The dried or fresh fruits are eaten. Fruits are fermented and prepared into a confection and ripe fruit is eaten raw. In central Sudan *Z. spina-christi* fruits are used to treat some diseases like diarrhea, malaria and as an antispasmodic.

In northern Kordofan State the poultice of the powdered leaves is used to heal swellings while macerated roots are used as an antipurgative.

The honey collected from the flowers is an excellent flavor.

The wood is used as a source of fuel and it produces an excellent charcoal.
Fig(1): Goats feeding on fallen leaves and fruits of *Z.spina-christi*.

...Seeds enclosed inside the hard endocarp

Fig(2): Leaves, spines, seeds and fruits of *Z.spina-christi*. 


Vernacular names:
Common English name : jujuba
Common Arabic names : bemba , Nabaj

**Botanical description:**

Trees or shrub or climbers, 1.8 – 8 m; bark grey, deeply furrowed; branches almost *zizag*, with single or paired spines of up to 12 mm. Leaves ovate to broadly ovate, alternate, up to 8 × 4.7 in, conspicuously 3 – veind from the base, dark green above with veins depressed, leathery, paler green below due to the dense rusty yellow to grey furry hairs, base lobed, markedly asymmetric; margin finely toothed; petiole up to 1.2 cm long , with dense soft hairs; stipules spinescent, short , hairy. Flowers small, star-shaped, creamy to yellowish – green, with an unpleasant sharp smell, in dense light clusters in the axils of the leaves, inconspicuous except when produced in profusion; pedicel 1 – 2 cm long. Fruit almost spherical, 2-3 cm in diameter, shiny red or reddish-brown when mature, smooth, containing 1 to 2 light brown glossy seeds inside the inner stone.

Flowering period : October – February.

Fruiting period : March-August.

**Distribution:**

In Darfur (J.Mara), Kordofan (Nuba Mts) , Upper Nile , (Shambe) , Bahr El Ghazal , Blue Nile (Roseires) and East Equatoria.
**Common uses:**

The Fruit pulp is sweet and hence fruits are used to make porridge and meal in western Sudan. Leaves provide good are animal fodder. A concoction of the bark and the leaves is used for respiratory ailment and septic swellings of the skin in Darfur. Fresh leaves are chewed and applied to wounds, boils and sores to reduce pain. The root bark is used as an emetic, febrifuge and laxative. *Z. abyssinica* is a source of firewood and it is used in the production of charcoal.

**3. Z. mauritiana Lam.**

Syn: *Z. jujuba* (L.) Lam.; *Z. jujuba* (L.) Gaertn; *Z. tomentosa* Poir; *Z. rotundata* DC.; *Z. aucheri* Boiss; *Z. insularis* Smith; *Z. sororia* Roem. and Schult.; and *Z. orthocantha* DC.

Vernacular names:

Common English names: bear tree, ber, Chinese apple, Chinese date, Indian jujube, Indian cherry and dunks.

Common Arabic names: nabak (fruit), Kanar

Sidr (tree).

**Botanical description:**

Shrubs, small or medium trees, 3 – 4 or 10 – 16 m tall, or semi-deciduous and much branched trees; bark with deep longitudinal furrows, greyish – brown or reddish, usually spiny, occasionally unarmed; branches densely white – pubescent, zig-zag, dull brown - grey. Leaves elliptic to ovate or nearly orbicular, apex rounded obtuse or subacute, base rounded or cuneate, symmetrical; margin serrulate; lamina with 3 prominent nerves almost to the apex, glabrous above, densely hairy
beneath; stipular spines 2, one hooked, the other straight. Inflorescence axillary cymes; peduncles and pedicels tomentose; ovary 2 – locular. Fruits glabrous, globose or oval edible drupes, ca 2.1 cm across and may reach 5 × 3 cm; pulp acidic, sweet, yellow or sometimes reddish.

**Distribution:**
Widespread on low lying ground near river beds or water depressions in the tall grass savanna of Darfur, Kordofan, Blue Nile, Upper Nile, Bahr El Ghazal, East Equatoria and Gezira State

**Common uses:**

Fruits are eaten fresh or crushed in water forming a very popular cold drink.

The leaves are used as fodder for animals. Fruits are used internally in the treatment of a range of conditions including chronic fatigue and loss of appetite.

The plant can be grown as a hedge. Wood is hard, compact, tough and can be used for turnery. It makes an excellent fuel and good charcoal.
Fig (3): (a) tree  (b) A branch  (c) fruits  (d) flower of *Z.abyssinica*. 
Fig. (4). *Z. mauritiana*. (a) = shrub  
(b) = Fruits and seeds  
(c) = A fruiting branch

*Syn:* *Z.mucronata Willd.*

**Vernacular names:**
Common English name: buffalo thorn.
Common Arabic names: *Zizouf*, nabag farisi.

**Botanical description:**
Armed shrubs or trees 12-15 m high; bark dark grey, fissured. Branchlets rusty, pubescent to almost glabrous, dark brown, zigzagging, spines 2, one straight and 2 cm long, the other sharply curved. Leaves ovate to broadly ovate, 2-11x1.5 – 7 cm; petioles up to 1.25 cm long. Inflorescence 7 – 25- flowered cymes, 10 – 15 mm long on peduncles 1 – 3 cm long; sepals 1.5 – 2 mm; stigmas 2. Fruit globose, 12 – 20 mm, thick, reddish or reddish brown at maturity, 2- seeded, rather acrid, bitter, scarcely edible.

**Flowering period:** June – December

**Fruiting period:** July- October.

**Distribution:**
This species grows in depressions or near banks of rivers and streams in the tall grass savanna of Darfur, Kordofan, Blue Nile, Bahr ElGhazal, Kassala, Upper Nile and Equatoria.

5. *Z.pubescens Oliv.*

*Syn:* *Z.pubescens Oliv.*

Unarmed shrubs or trees 10-18 m high; bark rough, dark grey brown, reticulately fissured; branchlets, zigzagging with short internodes. Leaves elliptic or oblong elliptic or lanceolate, 3 – 8x 1.5 – 4 cm; petioles 3 – 6 mm long; stipules subulate, 1-2 mm long. Inflorescence auxiliary, 8 – 20 - flowerd cymes 0.5 – 1 cm long; flowers yellow green,
numerous; sepals 5, about 1.5 mm, narrow; ovary 2-celled; stigmas 2. Fruit ellipsoid, yellow or red yellow, 7-10 mm long, edible.
Flowering period: December – January.
Fruiting period: February.

**Distribution:**
Usually riverain in tall grass savanna in Equatoria.

**4.2 Chemical Studies:**

**4.2.1 Ash content:**

*Ziziphus mauritiana*, Gezira had the highest ash content, whereas *Z. abyssinica*, Darfur and *Z. spina-christi* had more or less similar values (Table 1). The ash content of *Z. mauritiana*, Gezira in this study agreed with Duke (1985) who found a value of 4.4%. However, the ash content for all of the *Ziziphus* spp. studied was higher than values reported by Parmar (1982), Duke (1985), Morton (1987) and Grosskinsky (1998) who found that *Z. mauritiana* fruit had ash contents of 1.4%, 3%, 3% and 2.8% respectively. The ash content of *Z. spina-christi* Kordofan was close to values of Duke (1985), (4.4%), Nour et al. (1987), (3.5%), Abdelgalil and Eljissry (1991) (4.4%) and Abdelmuti (1991) (4.4%). However, the ash content of *Z. spina-christi* in this study was lower than that cited by Getachew (2001).

Results of statistical analysis for the ash content of the three *Ziziphus* spp. revealed that there are significant differences among these species in their ash content (Table 1). Moreover, there was a significant difference between the ash contents of *Z. mauritiana* Gezira and *Z. spina-christi* Kordofan (Table 5).

The ash content of *Z. abyssinica* was close to that of *Z. spina-christi* and hence an insignificant difference was found between these two
species (Table 6). The ash content of *Z.abyssinica*, Darfur (4.2) was higher than that reported by Russel (1947) (3.7%).

It was observed that the ash content of *Z.abyssinica*, Darfur was lower than that of *Z.mauritiana*, Gezira and that a statistically significant difference was found between the ash contents of these two species (Table 1).

### 4.2.2 Moisture Content:

The lowest and highest moisture contents were found to be 5.4% for *Z. spina-christi*, Kordofan and 80.3% for *Z.mauritiana*, Gezira, respectively (Table 1). The moisture contents of *Z.spina-christi*, Kordofan (5.4%) and *Z. abyssinica*, Darfur (5.5%) were comparable to that reported by Nour et al. (1987) who found that *Z.spina-christi* had a moisture content of 6.00%. However, the moisture content of *Z.spina-christi* was lower than that reported by Duke (1985) and Getachew (2001) who reported values of 9.3% and 7.6%, respectively.

*Z.abyssinica*, Darfur had a moisture content of 5.5%, a value comparable to that reported by Boynes (1940) who found a value of 6.00% for that species. However, this value was lower than that reported by Benhura and Katayi – Chidewe (2000) who reported a value of 9.1%. The moisture content of *Z.spina-christi*, Kordofan (5.4%) was more or less similar to the moisture content of *Z.abyssinica*, Darfur (5.5%).

Results of statistical analysis revealed that there are significant differences among the moisture contents of the *Ziziphus* spp. (Table 1). However, there was an insignificant difference between the moisture contents of these two species. The moisture content of *Z.mauritiana*, Gezira was in agreement with those of Morton (1987) and Pareek (2001) who found values of 81%, 81.6% and 81.6% - 83%. However, the moisture content of *Z.mauritina* Gezira was in agreement with that of Bal
(1992), Pareek, (2001), Morton, (1987) who found values of 81%, 81.6%, 81.6% - 83% for this species. However, the moisture content of *Z.mauritiana* Gezira was lower than that cited by (Li et al., 2007) who found a value of (87%) for the moisture content of this species. The moisture content of *Z.spina-christi*, Kordofan (5.4%) was lower than that of *Z.mauritiana* Gezira (80.3%), and that a significant difference was found between the moisture content of these two species (Table 5). Similarly, the moisture content of *Z.abyssinica*, Darfur was lower than that of *Z. mauritiana*, Gezira and that a significant difference was found between the moisture contents of these two species (Table 1).

### 4.2.3 Crude protein content:

The crude protein ranged from 2.90% in *Z.mauritiana*, Gezira to 4.10% in *Z.spina-christi* Kordofan (Table 1). The crude protein content of *Z.spina-christi* Kordofan was in agreement with Duke (1985) and Abdelgalil and Eljissry (1991) who found values of 4.8% and 4.8 – 5.6% respectively. Other authors such as Abdelmuti (1991), Eden (1992) and Getachewo (2001) reported lower values of 2.8%, 3.1% and 3.2%, respectively for the crude protein of this species. The crude protein content of *Z.mauritiana* was 2.9% which was more or less comparable to values reported by Parmar (1982), Von Maydell (1986) and Pareek (2001) who found values of 2.6%, 2.5% and 2.9, respectively.

The crude protein content of *Z.mauritiana*, Gezira was lower than that of *Z.spina-christi*, Kordofan and that a significant difference was found between the crude protein content of these two species (Table 5). *Z.abyssinica* Darfur had a crude protein of 3.95%, a value which was higher than values reported by Rittner and Reel (1992) (1.4%) and Benhura and Katayi-Chedewe (2000) (2.6%), respectively. However, this value is lower than that reported by Russel (1947), who found a value of 9.8% of crude protein for this species.
The crude protein content of *Z.abyssinica*, Darfur (3.95%) was higher than that of *Z.mauritiana*, Gezira (2.9%) and thus a significant difference was found between the crude protein contents of these two species (Table 1). The crude protein content of *Z.spina-christi*, Kordofan was close to that of *Z.abyssinica*, Darfur and an insignificant difference was found between these two species (Table 6).

### 4.2.4 Fat Content:

*Z.spina-christi*, Kordofan had the highest fat content (0.90%) whereas *Z.mauritiana*, Gezira had the lowest (0.30%) (Table 1). The fat content of *Z.spina-christi*, Kordofan was similar to that reported by Duke (1985), Berry *et al.* (1990) and Abdelgalil and Eljissry (1991) who each reported a value of 0.9%. This value is higher than that cited by Nour *et al.* (1987) who found a value of 0.8% but it is lower than that of Getachew (2001) who found a value of 1.1%. The fat content of *Z.spina-christi*, Kordofan was higher than values reported by Abdelmuti (1991) and Eden (1992) who found values of 2.1% and 2.2%, respectively.

The fat content of *Z. mauritiana*, Gezira was similar to values reported by (Li *et al.*, 2007). It is also within the range cited by (Morton, 1987) and (Grosskinsky, 1998). However, it was lower than that of *Z.spina-christi*, Kordofan (0.90%) and a significant difference was found between these two species (Table 5).

The fat content of *Z.abyssinica*, Darfur was 0.80%. This value was higher than values reported by Babayemi (2007) and Russel (1947), who reported values of 0.50% and 0.20%, respectively.

It was also found that the fat content of *Z.abyssinica*, Darfur (0.80%) was higher than that of *Z.mauritiana*, Gezira (0.30%).

Results of statistical analysis showed significant differences among the *Ziziphus* species in their fat content (Table 1). Similarly a significant
difference was found between the fat contents of *Z.mauritiana*, Gezira and *Z.abyssinica*, Darfur (Table 1). However, the fat content of *Z.abyssinica*, Darfur was close to that of *Z.spina-christi*, Kordofan and an insignificant difference was found between these two species (Table 6).

### 4.2.5 Fiber Content:

The highest value of fiber content was found in *Z.mauritiana*, Gezira (3.8%) and the lowest was in *Z.abyssinica*, Darfur (2.4%) (Table 1). The fiber content of *Z.mauritiana*, Gezira was in agreement with Duke (1985) and Grossinky (1998) who reported values of 4% and 3.4%, respectively. However, the fiber content of this species was higher than results reported by Moton (1987) and (Li et al., 2007) who found values of 1.2% and 2.8%, respectively.

The fiber content of *Z.abyssinica*, Darfur was comparable to that of Russel (1947) who found values of 2.6%.

Results of statistical analysis revealed significant differences among the *Ziziphus* spp. in their fiber content (Table 1). Similarly, a significant difference was found between *Z.mauritiana*, Gezira and *Z.abyssinica*, Darfur in their fiber content (Table 4).

The fiber content of *Z.spina-christi*, Kordofan (2.50%) was lower than those of Nour et al (1987), Abdelgalil and Eljissry (1991), Abdelmuti (1991) and Getachew (2001) who found values of 3.5%, 4.1%, 4.1% and 4.7% respectively.

The fiber content of *Z.mauritiana*, Gezira was higher than that of *Z.spina-christi*, Kordofan and that a significant difference was found between the fiber content of these two species (Table 5). However, an insignificant difference was found between *Z.abyssinica*, Darfur and *Z.spina-christi*, Kordofan in their fiber content (Table 6).
4.2.6 Total carbohydrates content:

The highest value of total carbohydrates was found in *Z.abyssinica*, Darfur (83.00%) and the lowest was in *Z.mauritiana*, Gezira (8.20%). (Table 1).

The total carbohydrates of *Z.spina-christi*, Kordofan (82.70%), were more or less comparable to those reported by Duke (1985), Nour et al.(1987) and Abdelmuti (1991) and Getachew. (2001) who found values of 80.9%, 86.1%, 80.1%, and 80.7% respectively.

The total carbohydrates of *Z.abyssinica*, Darfur (83%) were lower than that of Benhura and Katayi-Chidewe (2000) who reported a value of 86% for the total carbohydrates of this species.

The total carbohydrates of *Z.mauritiana*, Gezira were 8.20%. This value was lower than that reported by Singh et al (1967), (13.6%), Jawanda et al. (1981) (12.8%), Von Maydell (1986) (12.8%) but it is higher than that of Morton (1987) (2.4%). The total carbohydrate of *Z.mauritiana*, Gezira (8.2%) was comparable to that of (Li et al., 2007) who reported a value of 8.8% for this species.

Results of statistical analysis revealed significant differences among the *Ziziphus* spp. (Table 1). Similarly, a significant difference was found between total carbohydrates of *Z.mauritiana*, Gezira and each of *Z.spina-christi*, Kordofan(Table 5) *Z.abyssinica*, Darfur in their carbohydrates contents (Table 1). However, insignificant differences were observed between the total carbohydrates of *Z.spina-christi*, Kordofan and *Z.abyssinica*, Darfur (Table 6).

4.2.6.1 Total Sugars:

The highest contents of total sugars (45.5%) was found in *Z.spina-christi*, Kordofan whereas the lowest (7.9%) was in *Z.mauritiana*, Gezira (Table 2).
The total sugars content for *Z. spina-christi*, Kordofan was in agreement with results of Nour *et al.* (1987) and Abdelmuti (1991) who each found a value of 47.6% for this species.

The total sugars content of *Z. mauritiana*, Gezira (7.90%) is within the range 3 - 9.6% reported by Pareek (2001). However, the total sugars content of this species was lower than that reported by Morton (1987), Von Maydell (1986) and Chovatia *et al.* (1993) who found values of 21.6%, 20 – 30% and 10.8%, respectively.

The total sugars of *Z. abyssinica*, Darfur (41.9%) was lower than that of *Z. spina-christi*, Kordofan (45.5%).

Results of statistical analysis revealed significant differences among the *Ziziphus* spp. in their total sugars% (Table 2). Similarly, a significant difference was found between the total sugars% of *Z. abyssinica*, Darfur and *Z. spina-christi*, Kordofan (Table 7). A significant difference was also found between the total sugars of *Z. mauritiana*, Gezira and *Z. spina-christi*, Kordofan (Table 8).

The total sugars of *Z. abyssinica*, Darfur (41.9%) was higher than that of *Z. mauritiana*, Gezira (7.9%) and a significant difference was found between these two species (Table 7).

### 4.2.6.2 Reducing sugars:

*Z. spina-christi*, Kordofan had highest total reducing sugars content (22.6%), whereas *Z. mauritiana*, Gezira had the lowest (6%) (Table 2). The total reducing sugars content of *Z. spina-christi*, Kordofan was in agreement with those of Nour *et al.* (1987), Abdelgalil and Eljissry. (1991), and Abdelmuti(1991).

The total reducing sugars content of *Z. mauritiana*, Gezira (9.7%) was comparable to values reported by Morton (1987) (1.4 – 6.2%), Chovatia *et al* (1993) (5.1%), Bal (1992) (5.6%) and Mathew(2002) (5.6%). The
total reducing sugars content of *Z.mauritiana*, Gezira (6%) was lower than that of *Z.spina-christi*, Kordofan (22.6%). Results of statistical analysis revealed significant differences among the *Ziziphus* spp. in their reducing sugars content (Table 2). Similarly there was a significant difference between the total reducing sugars of these two species (Table 8).

The total reducing sugars of *Z.abyssinica*, Darfur (21.5%) was much higher than that of *Z.mauritiana*, Gezira (6%) and a significant difference was found between the total reducing sugars of these two species (Table 7). However, an insignificant difference was found between *Z.abyssinica*, Darfur and *Z.spina-christi*, Kordofan in their total reducing sugars content (Table 7).

**4.2.6.3 Sucrose:**

The highest sucrose content was found in *Z.spina-christi*, Kordofan while the lowest was in *Z.mauritiana*, Gezira (Table 2). The sucrose content of *Z.spina-christi*, Kordofan was comparable to values reported by Nour et al. (1987), Abdelgalil and Eljissry (1991) and Abdelmuti (1991) who found values of 21.8%, 21.8%, 21.8%, respectively.

The sucrose content of *Z.amuritiana*, Gezira (1.9%) was lower than results of Morton (1987) and Chovatia et al (1993) who found values of 15.4% and 5.7%, respectively.

Results of statistical analysis revealed significant differences among the *Ziziphus* spp. in their sucrose content. Similarly, a significant difference was found between sucrose content of *Z.mauritiana*, Gezira and *Z.spina-christi*, Kordofan (Table 8).

A significant difference was also found between the sucrose content of *Z.abyssinica*, Darfur and that of *Z.mauritiana*, Gezira (Table 7). Moreover, a significant difference was also found between the sucrose
content of *Z.abyssinica* Darfur and that of *Z.spina-christi*, Kordofan (Table 7).

### 4.3 Mineral Composition:

#### 4.3.1 Ca:

*Z.abyssinica*, Darfur had the highest Ca content whereas *Z.mauritiana*, Gezira had the lowest (Table 3). *Z.spina-christi*, Kordofan was found to contain 0.85 Ca. This result was in agreement with that of Nour *et al.* (1987), Abdelgalil and Eljissry. (1991) and Abdelmuti(1991) who found values of 1.4%, 0.61% and 0.6% and 0.6% respectively. However, this value was lower than findings reported by Duke (1985), Berry *et al.* (1990) and Eden (1992) who reported values of 1.4%, 1.4% and 1.7%, respectively.

Results of statistical analysis among the Ca contents of *Zizphus spp.* (Table 3).

*Z.mauritiana*, Gezira had 0.80% of Ca, a value that was slightly lower than that of Duke (1985) who reported a value of 1.3% for Ca content. Furthermore, the Ca content of this species was much lower than results reported by Morton (1987) and Grosskinsky (1998) who founds values of 2.5% and 2.1% respectively.

A significant difference was found between the Ca content of *Z.mauritiana*, Gezira and *Z.spina-christi*, Kordofan. (Table 9). *Z.abyssinica*, Darfur was found to contain 1.25% Ca, and a significant difference was found between the Ca content of this species and *Z.spina-christi*, Kordofan (Table 7). There was also a significant difference was between the Ca content of *Z.abyssinica*, Darfur and *Z.mauritiana* Gezira. (Table 10)
4.3.2 Mg:

*Ziziphus spina-christi*, Kordofan had the highest Mg content whereas *Z.mauritiana*, Gezira had the lowest (Table 3). *Z.abyssinica*, Darfur was found to contain (0.45%) Mg compared to a (0.50%) for *Z.spina-christi*, Kordofan. The Mg content of *Z.spina-christi*, Kordofan was in agreement with that of Eden (1992), who reported a value of 0.56%. but it was higher than that reported by Abdelgalil and Eljissry (1991) and Abdelmuti(1991) who found values of 0.12% and 0.10%, respectively.

Results of statistical analysis revealed significant differences in the Mg content of the *Ziziphus* spp. (Table 3). However, an insignificant difference was found between the Mg contents of the *Z.abyssinica*, Darfur and *Z.spina-christi*, Kordofan. (Table 9).

*Z.mauritiana*, Wadrawah was found to contain 0.225% Mg, a finding that was in agreement with Grosskinsky (1998) who found a value of 0.3%. A significant difference was found between the Mg content of *Z.mauritiana*, Gezira and *Z.spina-christi*, Kordofan (Table 9).

Mg content of *Z.abyssinica*, Darfur (0.45%) was higher than that *Z.mauritiana*, Gezira (0.225%) and a significant difference was found between the Mg content of these two species (Table 10).

4.3.3 Fe:

The highest Fe content was in *Z.spina-christi*, Kordofan and the lowest was in *Z.abyssinica*, Darfur (Table 3).

The Fe content of *Z.spina-christi*, Kordofan was comparable to values reported by Duke (1985), Berry et al. (1990), Abdelgalil and Eljissry (1991) and Eden (1992) who reported values of 0.03%, 0.02%, 0.03% and 0.06%, respectively. Results of statistical analysis revealed significant differences among the Fe content of the *Ziziphus* spp. (Table 3).
There was a significant difference between the Fe content of *Z. abyssinica*, Darfur (0.0192%) and *Z. spina-christi*, Kordofan (Table 9). The Fe content of *Z. mauritiana*, Gezira (0.0242) was comparable to values reported by Duke (1985) and Morton (1987) who reported values of 0.035% and 0.07%, respectively. However, the Fe content of *Z. mauritiana*, Gezira was lower than that reported by Grosskinsky (1998). A significant difference was found between the Fe content of *Z. spina-christi*, Kordofan and *Z. mauritiana*, Gezira (Table 9). Similarly, a significant difference was also found between *Z. abyssinica*, Darfur and *Z. mauritiana*, Gezira in their for Fe content (Table 10).

### 4.3.4 P:

*Z. mauritiana*, Gezira had the highest value of P content whereas *Z. spina-christi*, Kordofan had the lowest (Table 3). *Z. abyssinica*, Darfur was found to contain 0.32% P, a value that was comparable to the value for *Z. spina-christi*, Kordofan (0.28%) . This P content was also in agreement with results reported by Russel (1947). The P content *Z. spina-christi*, Kordofan was the lowest compared to values reported by Nour et al. (1987), Eden (1992) who found values of 1.06% and 1.3%, respectively. P content of *Z. mauritiana*, Gezira (0.44%) was lower than that reported by Duke (1985) who found a P content of 1.6%. However, this value agreed with values found by Morton (1987) and Grossky (1998) (0.26% and 0.56%), respectively.

Results of statistical analysis revealed significant differences among the P contents of *Ziziphus* spp. (Table 3). A significant difference was also found between the P content of *Z. mauritiana* Gezira and *Z. spina-christi*, Kordofan. (Table 9). Similarly, a significant difference was found between the P content of *Z. abyssinica*, Darfur and that of *Z. mauritiana*, Gezira (Table 10).
4.4 Organic acids:

4.4.1 Ascorbic acid:

The highest value of ascorbic acid was found in *Z.mauritiana*, Gezira while the lowest was found in *Z.spina-christi*, Kordofan (Table 4). The scorbic acid content of *Z.spina-christi*, Kordofan was lower than values reported by Duke (1985), Abdelgalil and Eljissry (1991), Abdelmuti (1991) and Getachwo (2001) who found values of 30 mg, 30 mg, 30 mg and 35 mg for the ascorbic acid of this species.

The scorbic acid of *Z.mauritiana*, Gezira was 18.66 mg, a value which was much lower than values reported by Bal and Mann (1978), Duke (1985), Morton (1987) and Grosskinsky (1998) who found values of 70-165 mg/100g, 30 mg, 66 – 76 mg/100g, and 24 mg/100g, respectively.

Results of statistical analysis revealed significant differences among the ascorbic acid contents of *Ziziphus* spp. (Table 4).

A significant difference was found between a scorbic acid content of *Z.spina-christi*, Kordofan and *Z.mauritiana*, Gezira, (Table 12). Similarly, there is a significant difference between the ascorbic acid content of *Z.mauritiana* Gezira and that of *Z.abyssinica*, Darfur (Table11).

The ascorbic acid content of *Z.abyssinica*, Darfur was 12.24 mg. This value was higher than that of *Z.spina-christi*, Kordofan, and a significant difference was found between the ascorbic acid content of these two species. (Table 11).

4.4.2 Citric Acid:

*Z.abyssinica*, Darfur had the highest content of citric acid while *Z.spina-christi*, Kordofan had the lowest (Table 4).
The citric acid content of *Z.mauritina*, Gezira was found to be 0.4203 mg. This value lies within the range (0.2 – 1.1 mg) reported by Morton (1987).

Results of statistical analysis revealed significant differences among the Citric acid content of the *Ziziphus* spp. (Table 4). A significant difference was found between the citric acid content of *Z.mauritiana*, Gezira and *Z.abbyssinica*, Darfur (Table 11).

The citric acid content of *Z.spina-christi*, Kordofan (0.4133) was close to that of *Z.mauritiana*, Gezira (0.4203) and an insignificant difference was found between the Citric acid content of these two species (Table 12).

The citric acid content of *Z.abyssinica*, Darfur was higher than that of *Z.spina-christi*, Kordofan and a significant difference was found between citric acid contents of these two species (Table 11).
Ziziphus Tourn. ex L.

Key to the species (based on chemical components)

A. Moisture content ca 80% ; fat 3% ; total carbohydrates ca 8%; reducing sugars 6%; sucrose ca 2%; ascorbic acid ca 19%. ………………………………………………Z.mauritiana.

AA. Moisture content ca 5.5% ; fat < 1%; total carbohydrates >82% ; reducing sugars > 21% ; sucrose > 19% ; ascorbic acid 8-12% :

B. Ascorbic acid < 9 %. …………………..Z.spina-christi

BB. Ascorbic acid > 12% . …………Z.abbyssinica.

Interpretation of results of chemical analysis.

It was seen that there were significant differences among the chemical components of the Ziziphus spp. In general and between Z.mauritiana on one hand and Ziziphus-christi and Z.absynica on the other hand . These differences could be attributed to edaphic and climatic factors .

Z.mauritiana Gezira grows in clay soil and Savannah climate whereas Z.spina-christi, Kordofan and Z. abyssinica, Darfur grow in sandy soil and semi-desert climate.
Table (1). Chemical Composition of fruits of *Ziziphus spina-christi*, *Z.abyssinica* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ash %</th>
<th>Moisture %</th>
<th>Crude protein %</th>
<th>Fat %</th>
<th>Fiber %</th>
<th>Carbohydrates %</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ziziphus spina-christi</em>, Kordofan</td>
<td>4.3</td>
<td>5.4</td>
<td>4.1 *</td>
<td>0.9 *</td>
<td>2.5</td>
<td>82.7</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td>4.2</td>
<td>5.5</td>
<td>3.95</td>
<td>0.8</td>
<td>2.4</td>
<td>83.00 *</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td>5.1 *</td>
<td>80.3 *</td>
<td>2.9</td>
<td>0.3</td>
<td>3.8 *</td>
<td>8.2</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Table (2). Total sugars, Reducing sugars and sucrose of fruits of *Z.spina-christi*, *Z.abyssinica* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total sugars</th>
<th>Reducing Sugars</th>
<th>Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ziziphus spina-christi</em>, Kordofan</td>
<td>45.5 *</td>
<td>22.6 *</td>
<td>21.7 *</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td>41.9</td>
<td>21.5</td>
<td>19.4</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td>7.9</td>
<td>6</td>
<td>1.9</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05
Table (3). Mineral composition of fruits of *Z.spina-christi*, *Z.abyssinica*, and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>Ca%</th>
<th>Mg%</th>
<th>Fe%</th>
<th>P%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Z.spina-christi</em>, Kordofan</td>
<td></td>
<td>0.85</td>
<td>0.50*</td>
<td>0.0377*</td>
<td>0.28</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td></td>
<td>1.25*</td>
<td>0.45</td>
<td>0.0192</td>
<td>0.32</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td></td>
<td>0.80</td>
<td>0.225</td>
<td>0.0242</td>
<td>0.44*</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Table (4). Ascorbic acid and citric acid contents of *Z.spina-christi*, *Z.abyssinica* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>Ascorbic acid (mg/100g)</th>
<th>Citric acid (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Z.spina-christi</em>, Kordofan</td>
<td></td>
<td>8.64</td>
<td>0.4133</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td></td>
<td>12.24</td>
<td>0.6164 *</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td></td>
<td>18.66 *</td>
<td>0.4203</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Table (5). Chemical composition of fruits of *Ziziphus spina-christi* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample</th>
<th>Ash %</th>
<th>Moisture %</th>
<th>Crude protein %</th>
<th>Fat %</th>
<th>Fiber %</th>
<th>Carbohydrates %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Ziziphus spina-christi,</em> Kordofan</td>
<td>4.3</td>
<td>5.4</td>
<td>4.1</td>
<td>0.9</td>
<td>2.5</td>
<td>82.7</td>
</tr>
<tr>
<td></td>
<td><em>Z.mauritiana,</em> Gezira</td>
<td><em>5.1</em></td>
<td><em>80.3</em></td>
<td><em>2.9</em></td>
<td><em>0.3</em></td>
<td><em>3.8</em></td>
<td><em>8.2</em></td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample</th>
<th>Ash</th>
<th>Moisture</th>
<th>Crude protein</th>
<th>Fat</th>
<th>Fiber</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Ziziphus spina-christi</em>, Kordofan</td>
<td>4.3</td>
<td>5.4</td>
<td>4.1</td>
<td>0.9</td>
<td>2.5</td>
<td>82.7</td>
</tr>
<tr>
<td></td>
<td><em>Z. abyssinica</em>, Darfur</td>
<td>4.2 NS</td>
<td>5.5 NS</td>
<td>3.95 NS</td>
<td>0.8 NS</td>
<td>2.4 NS</td>
<td>83.00 *</td>
</tr>
</tbody>
</table>

* Significant (P = 0.05)
NS = Non- significant
Table (7). Total sugars, Reducing sugars and sucrose of fruits of *Z.spina-christi* and *Z.abyssinica* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total sugars</th>
<th>Reducing Sugars</th>
<th>Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample</strong></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td><em>Ziziphus spina-christi</em>, Kordofan</td>
<td>45.5*</td>
<td>22.6 *</td>
<td>21.7 *</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td>41.9</td>
<td>21.5</td>
<td>19.4</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td>7.9</td>
<td>6</td>
<td>1.9</td>
</tr>
</tbody>
</table>

* Significant at  \( P = 0.05 \)
Table (8). Total sugars, Reducing sugars and sucrose of fruits of \textit{Z.spina-chriti} and \textit{Z.mauritiana}.

<table>
<thead>
<tr>
<th>Parameter Sample</th>
<th>Total sugars</th>
<th>Reducing sugars</th>
<th>Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Ziziphus spina-christi,}</td>
<td>45.5 *</td>
<td>22.6 *</td>
<td>21.7 *</td>
</tr>
<tr>
<td>Kordofan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Z.mauritiana,} Gezira</td>
<td>7.9</td>
<td>6</td>
<td>1.9</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05
Table (9): Mineral composition of fruits of *Z.spina-christi* and *Z.abyssinica* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>Ca%</th>
<th>Mg%</th>
<th>Fe%</th>
<th>P%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Z.spina-christi</em>, Kordofan</td>
<td></td>
<td>0.85</td>
<td>0.50*</td>
<td>0.0377*</td>
<td>0.28</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td></td>
<td>1.25*</td>
<td>0.45</td>
<td>0.0192</td>
<td>0.32</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td></td>
<td>0.08</td>
<td>0.225</td>
<td>0.0242</td>
<td>0.44*</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Table (10). Mineral composition of fruits of *Z.abyssinica*, and *Z.mauritiana*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>Ca%</th>
<th>Mg%</th>
<th>Fe%</th>
<th>P%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td></td>
<td>1.25 *</td>
<td>0.45 *</td>
<td>0.0192</td>
<td>0.32</td>
</tr>
<tr>
<td><em>Z.mauritina</em>, Gezira</td>
<td></td>
<td>0.80</td>
<td>0.225</td>
<td>0.0242*</td>
<td>0.44*</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Table (11). Ascorbic acid and citric acid contents of *Z.spina-christi* and *Z.abyssinica* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ascorbic acid (mg/100g)</th>
<th>Citric acid (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Z.spina-christi</em>, Kordofan</td>
<td>8.64</td>
<td>0.4133</td>
</tr>
<tr>
<td><em>Z.abyssinica</em>, Darfur</td>
<td>12.24 *</td>
<td>0.6164 *</td>
</tr>
<tr>
<td><em>Z.maurutiana</em>, Gezira</td>
<td>18.66 *</td>
<td>0.4203</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Table (12). Ascorbic acid and citric acid contents of *Z.spina-christi* and *Z.mauritiana*.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ascorbic acid (mg/100g)</th>
<th>Citric acid (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Z.spina-christi</em>, Kordofan</td>
<td>8.64</td>
<td>0.4133</td>
</tr>
<tr>
<td><em>Z.mauritiana</em>, Gezira</td>
<td>18.66 *</td>
<td>0.4203</td>
</tr>
</tbody>
</table>

* Significant at P = 0.05.
Chapter (5)

Summary and Recommendations:

5.1 Summary and conclusions:

This work is a chemotaxonomic study on the genus *Ziziphus* in the Sudan. It is composed of two parts: Taxonomic and chemical studies.

5.1.1. Taxonomic Studies:

A field survey of the genus *Ziziphus* in the Sudan revealed that members of the genus occur in many parts of the Sudan but they are of wide occurrence in the states of Kordofan, Darfur and Gezira. Five species were identified namely: *Z.spina-christi*, *Z.abyssinica* and *Z.mauritiana*, *Z.mucronata* and *Z.pubescens*.

Scientific names and vernacular names have been provided and synonyms have been updated. Brief botanical descriptions have been provided together with notes on geographical distribution and common uses in the Sudan.

5.1.2. Chemical Studies:

The fruits of *Ziziphus spina-christi*, Kordofan, *Z.abyssinica*, Darfur and *Z.mauritiana*, Wadrawah have been chemically analysed for a number of chemical components (Table 17). The following is a brief summary of the results of the chemical analysis:

Ash content:

*Z.mauritaina*, Wadrawah had the highest ash content while *Z.abyssinica*, Darfur and *Z.spina-christi*, Kordofan had more or less similar ash contents.

Significant differences were found among the three *Ziziphus* spp. in their ash content (Table 17).
**Moisture Content:**

*Z.mauritiana*, Wadrawah had the highest moisture content (80.3%) while *Z.spina-christi*, Kordofan and *Z.abyssinica*, Darfur had more or less similar values.

Significant differences were found among the moisture contents of the three *Ziziphus spp.* (Table 17).

**Crude Protein:**

The highest crude protein content was found in *Z.spina-christi*, Kordofan (4.1%) and the lowest was in *Z.mauritiana*, Wadrawah (2.90%). Significant differences were found among protein contents of the three *Ziziphus spp.* (Table 17).

**Fat Content:**

*Z.spina-christi*, Kordofan had the highest fat content (0.90%) whereas *Z.mauritiana* had the lowest (0.30%).

Significant differences were found among fat contents of the three *Ziziphus spp.* (Table 17).

**Fiber Content:**

The highest fiber content was found in *Z.mauritiana*, Wadrawah (3.20%) and the lowest found in *Z.abyssinica*, Darfur.

Significant differences were found among the fiber contents of the three *Ziziphus spp.* (Table 17).

**Carbohydrates Content:**

The highest value of Carbohydrates was found in *Z.abyssinica*, Darfur (83.00%) and the lowest was found in *Z.mauritiana*, Wadrawah (8.20%).

Significant differences were found among the carbohydrates of the three *Ziziphus spp.* (Table 17).
**Total Sugars:**

The total sugars contents ranged from (7.9%) *Z.mauritiana*, Wadrawah to 45.5% in *Z.spina-christi*, Kordofan.

Significant differences were found among the total sugars contents of the three *Ziziphis* spp. (Table 17).

**Reducing Sugars:**

*Z.spina-christi*, Kordofan had the highest content of reducing sugars (22.60%) while *Z.mauritiana*, Wadrawah had the lowest (6.00%). Significant differences were found among the reducing sugars contents of the three *Ziziphus* spp. (Table 17).

**Sucrose:**

The highest sucrose content was in *Z.spina-christi*, Kordofan (21.7%) whereas the lowest was in *Z.mauritiana*, Wadrawah. Significant differences were found among the sucrose contents of the three *Ziziphus* spp. (Table 17).

**Ca:**

*Z. abyssinica*, Darfur had the highest Ca content (1.25%) whereas *Z.mauritiana*, Wadrawah had lowest (0.80%).

Significant differences were found among the three *Ziziphus* spp. in their Ca contents (Table 17).

**Mg:**

*Z.spina-christi*, Kordofan had the highest Mg content (0.50%) whereas *Z.mauritiana*, Wadrawah had lowest (0.225%).

Significant differences were found among the Mg contents of the three *Ziziphus* spp. (Table 17).

**Fe:**

The highest Fe content was in *Z.spina-christi*, Kordofan (0.377%) and the lowest was in *Z.abyssinica*, Darfur (0.0192%).
Significant differences were found among the Fe contents of the three Ziziphus spp. (Table 17).

**P:**

*Z.mauritiana*, Wadrawah had the highest P content (0.44%) whereas *Z.spina-christi*, Kordofan had the lowest (0.28%).

Significant differences were found among the P contents of the three Ziziphus spp. (Table 17).

### 5.1.3 Organic acids:

Two organic acids were found in the three Ziziphus spp. namely: ascorbic and citric acids.

**Ascorbic acid:**

The highest content of ascorbic acid was found in *Z.mauritiana*, Wadrawah while the lowest was found in *Z.spina-christi*, Kordofan.

Significant differences were found among the ascorbic acid contents of the three Ziziphus spp. (Table 17).

**Citric acid:**

The citric acid content of *Z.abyssinica* Darfur was (0.6164mg/100g) while that of *Z.spina-christi*, Kordofan was 0.4133.

Significant differences were found among the three Ziziphus spp. in their citric acid contents (Table 17).
### Table (17). Summary of Results of the Chemical Analysis

Of fruits of *Ziziphus spina-christi*, *Z.abyssinica* and *Z.mauritiana*

<table>
<thead>
<tr>
<th>Sample Parameter</th>
<th><em>Z.spina-christi</em> Kordofan</th>
<th><em>Z.abyssinica</em> Darfur</th>
<th><em>Z. mauritiana</em> Wadrawah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash content %</td>
<td>4.3 g/100g</td>
<td>4.2 g/100g</td>
<td>5.1* g/100g</td>
</tr>
<tr>
<td>Moisture content %</td>
<td>5.4 g/100g</td>
<td>5.5 g/100g</td>
<td>80.3* g/100g</td>
</tr>
<tr>
<td>Crude protein %</td>
<td>4.1* g/100g</td>
<td>3.95 g/100g</td>
<td>2.9 g/100g</td>
</tr>
<tr>
<td>Fat content %</td>
<td>0.9* g/100g</td>
<td>0.8 g/100g</td>
<td>0.3 g/100g</td>
</tr>
<tr>
<td>Fiber content %</td>
<td>2.5 g/100g</td>
<td>2.4 g/100g</td>
<td>3.2* g/100g</td>
</tr>
<tr>
<td>Carbohydrates %</td>
<td>82.7 g/100g</td>
<td>83.00* g/100g</td>
<td>8.2 g/100g</td>
</tr>
<tr>
<td>Total sugars %</td>
<td>45.5* g/100g</td>
<td>41.9 g/100g</td>
<td>7.9 g/100g</td>
</tr>
<tr>
<td>Reducing sugars %</td>
<td>22.6* g/100g</td>
<td>21.5 g/100g</td>
<td>6.00 g/100g</td>
</tr>
<tr>
<td>Sucrose %</td>
<td>21.7* g/100g</td>
<td>19.4 g/100g</td>
<td>1.9 g/100g</td>
</tr>
<tr>
<td>Ca %</td>
<td>0.85 g/100g</td>
<td>1.25* g/100g</td>
<td>0.80 g/100g</td>
</tr>
<tr>
<td>Mg %</td>
<td>0.50* g/100g</td>
<td>0.45 g/100g</td>
<td>0.225 g/100g</td>
</tr>
<tr>
<td>Fe %</td>
<td>0.0377* g/100g</td>
<td>0.0192 g/100g</td>
<td>0.0242 g/100g</td>
</tr>
<tr>
<td>P %</td>
<td>0.28 g/100g</td>
<td>0.32 g/100g</td>
<td>0.44* g/100g</td>
</tr>
<tr>
<td>Ascorbic acid mg/100g</td>
<td>8.64 mg/100g</td>
<td>12.24 mg/100g</td>
<td>18.66 mg/100g</td>
</tr>
<tr>
<td>Citric acid mg/100g</td>
<td>0.4133 mg/100g</td>
<td>0.6164* mg/100g</td>
<td>0.4203 g/100g</td>
</tr>
</tbody>
</table>

* significant at P= 0.05
5.2. Recommendations:

Ziziphus fruits or ber are highly nutritious and can provide a good famine food at times of food scarcity. So the author recommends the following:

- *Ziziphus* spp. should be included in all food security and polices programs.
- Provision of good storage facilities of ber fruits, especially the fruits of *Z.mauritiana*. This is because the moisture content of the ber fruits of *Z.mauritiana* is very high which greatly encourages microbial infection.
- Propagation and domestication of *Ziziphus* spp. In the Sudan particularly in arid and semi-arid regions of the Sudan.
- Provision of modern facilities for processing and packaging of ber fruits for export.
References


• Singh, S., Krishnamurthy, S. and Katyal, S.L. (1967). Fruit culture in India. ICAR, New Delhi, India.


