Comparison Between The Effects Of Mesquite (*Prosopis sp*. L.) Manure And NPK Fertilizer On Fodder Sorghum (*Sorghum bicolor*. L) In Sandy Soil Potting Mixtures

By

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DEDICATION

I dedicate this Thesis to

My Father

My Mother

My Brothers

My Sisters

Dear Haytham

Soul of Grand mother

For their encouragement

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ABSTRACT

Title: Comparison Between The Effects Of Mesquite (*Prosopis sp.*L) Manure And NPK Fertilizer On Fodder Sorghum (*Sorghum bicolor*. L) In Sandy Soil Potting Mixtures

The study was carried out in the year 2005 at the Faculty of Forestry Nursery, University of Khartoum, Shambat with the main objective of determination of the effect of mesquite manure on the growth of *Sorghum bicolor*, raised in sandy soil potting mixtures, compared with the complex chemical fertilizer NPK. Five treatments were used; three of them used different weights of mesquite manure: 12g (M12), 24g (M24) and 48g (M48) respectively, the fourth was the addition of 270g of complex chemical fertilizer NPK and the last one was the control without any addition.

Results showed that the stronger effect on sorghum height was induced by M48. The mean sorghum height in this treatment was 4m at the end of week 12. The mean sorghum shoot heights in the treatments were in the following ascending order: control < NPK < M24 < M12 < M48. Mesquite manure application has produced positive effect on the sorghum root development and growth. The highest root length was found in the highest manure application, so that the length in this treatment was more than 1.7 times higher than in the control. Trends of calculated shoot/root ratio were in conformity with shoot and root length growth out lined precedently. The general pattern of these ratios was: control < NPK< M12 = M24

< M48. The ratio values showed that root length in the control was about one third of the shoot, while it was only one eighth of the shoot length in the treatment with the highest mesquite manure application. Trends of sorghum weight development in the different treatments were very much similar to those discerned for the height, i.e. the highest weight was found in treatment M48, medium in treatment M12 and lowest in NPK and the control. As a result sorghum shoot dry weight of treatment M48 was significantly different ($P < 0.0001$) from all other treatments.

For the sorghum root dry weight, M48 was significantly different from the control and NPK, while they were not significantly different between them selves; also, there was no significant difference between the control and NPK treatment.

Percent shoot dry matter in all treatments, shower that the greatest value was for M48 (42%) and the lowest for M24, while it oscillated around 30% for M12, NPK and control.

ملخص البحث

العنوان: مقارنة بين تأثير سماد المسكيت و سماد النيتروجين الفسفوري المركب علي نمو و تطور علف الذرة (أبوسبعين)

اجريت هذه التجربة الحقلية عام 2005 بمشتل كلية الغابات جامعة الخرطوم لتحديد اثر بدرة اوراق المسكيت على نمو علف ابو سبعين فى التربة الرملية ومقارنته بالسماد الكيميائى المركب(NPK). استخدمت خمس معاملات، ثلاث منها تحتوى على اوزان مختلفة من بدرة اوراق المسكيت 12جرام (M12),24 جرام (M24) و48جرام (M48) على التوالى، المعاملة تحتوى على 270 جرام من السماد الكيميائى المركب والمعاملة الاخيرة هى الشاهد.

وقد اوضحت الدراسة ان الاثر الاكبر على ارتفاع نباتات العاف ممثلا في المعاملة 48 جرام من اوراق المسكيت وكان متوسط ارتفاع العاف فى هذه المعاملة 4 امتار فى اخر قراءات اخذت لهذه التجربة, متوسط ارتفاع العاف للمعاملات المختلفة كالاتى: 48 جرام > 24 جرام > 12 جرام > 270جرام سماد مركب > شاهد.

المعاملات الثلاث المحتوية علىاوراق المسكيت اعطت نتائج موجبة فى تطور ونمو الجذور. اعلى طول للجذور كان ايضا ممثلا فى المعاملة 48 جرام من اوراق المسكيت . حيث ان طول الجذور بلغ 1.7 ضعف الشاهد.

وفى اتجاه حساب نسبة ارتفاع النباتات الى طول الجذور نجد ان النسبة كانت كالاتى : الشاهد < 270 جرام سماد مركب < 12 جرام = 24 جرام < 48 جرام. وقد اوضحت هذه النسبة ان طول الجذور فى الشاهد تمثل 1/3

من ارتفاع النباتات, بينما تمثل 1/8 من ارتفاع العلف فى المعاملة 48 جرام. كما ان وزن العلف الرطب والجاف والنسبة بينهما فى جميع المعاملات يختلف بصورة تشابه الاختلاف فى الارتفاع, حيث ان اعلى وزن وجد فى المعاملة 48 جرام والمتوسط وجد فى 24 جرام و12 جرام والمنخفض فى السماد المركب والشاهد. وقد اشارت النتائج الى ان وزن العلف الجاف فى 48 جرام يختلف اختلافا معنويا عن بقية المعاملات الاخرى. وان وزن الجذور الجاف يختلف اختلافا معنويا عن الشاهد والسماد المركب الا انه لا يختلف عن بقية معاملات اوراق المسكيت الاخرى, كما انه لا يوجد اختلافا معنويا بين الشاهد والسماد المركب. اعلى نسبة للمادة العضوية ممثلة فى المعاملة 48 جرام (42%) وأ دناها في المعاملة 24 جرام بينما البقية توجد حول 30% (12جرام, الشاهد والسماد المركب).

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Chapter I

Introduction

Farmers have long known that certain substances, when added to the soil improve production, these are known as fertilizers. For cost and easy usage, chemical fertilizers have replaced natural ones. Although plants cannot distinguish the difference between these substances, artificial fertilizers can easily be overused resulting in damage to soil, rivers and oceans (Anthoni, 2000). Worldwide, much land has been degraded, and it is time to stop the destructive uses of land and to institute a serious reversal of land degradation. Biological nitrogen fixation can play a role in land remediation (Herridge and Ladha, 1995). All soils were not formed equally, thus, the yields that can be obtained on a specific soil will vary with the soil's capacity to supply plant-available moisture and nutrients. For producing profitable forage, and for maintaining soil productivity over years, fertilizer use is an important factor. N, P and K are needed in most fields to support forage production at economic levels, produce quality forage and to replace nutrients removed in forage harvests (Wysor, 2005). The role of trees, particularly leguminous ones, in improving soil fertility status is very important due to the fact that chemical fertilizers are expensive and the fallow periods are short (NAS, 1977). On degraded soil with typically low organic matter content, regular manuring application with forage legumes increase soil nitrogen and organic matter over extended periods. Legume manures offer several advantages over conventional fallows as they tend to improve, enrich and protect the soil (Wysor, 2005). In the Sudan, use of plant residues and animal dung as fertilizers is well known in traditional agriculture, particularly for orchard crops. Mesquite (*Prosopis chilensis*, (Moina) Stuntz) is one of the rapid growing and spreading plants, since it is a legume, it can provide substantial quantities of nutrients through its litter fall and decomposition.

The objectives of this study were:

1- To investigate effects of mesquite manure on physical and chemical properties of a sandy soil;

2- To assess effects of mesquite manure compared with NPK fertilizer, on growth and development of *Sorghum bicolor*.

Chapter II

Literature Review

1- *Prosopis species*

1.1- Description

Prosopis species is found either as a densely branched shrub about one meter high or a tree, which can reach 15 meters or more in height. The leaves are dark green and divided into numerous small fern-like leaflets. Most varieties have minute hairs on both surfaces. The twigs are smooth barked and armed with straight spines, which vary in size; but may reach a length of 10 cm. They are usually, arranged, in pairs rising from the leaf base. The wood is hard and reddish brown with yellow sapwood. In the, United States of America, it is highly valued as a decorative timber and as a fuel for barbecues. The flowers are small and greenish–yellow. They are borne near the ends of the branches in cylindrical clusters, 5 to 8 cm long. The pods are sickle shaped and flattened. They vary from 10 to 20 cm in length and about 1 cm in width. Some times the pods are constricted between the seeds. They are usually green and fleshy, turning hard and straw–colored when ripe, but some plants bear purple flecked pods. Each pod contains 10 to 20 seeds embedded in sweet pulp. Seedlings of mesquite trees are often confused with prickly acacia (*Acacia farnesiana*), also known as minidgarra; the seedling of the later species have small grey twigs with wart (Tom and Watson, 2003). In the Sudan, *Prosopis sp.* that are naturalized include *P. glandulosa*, *P. chilensis* and *P. juliflora*.

Prosopis africana is indigenous to Sudan; it is usually deciduous, with characteristics similar to both *P. juliflora* and *P. chilensis* that is why it has been incorrectly identified as *P. chilensis* (Abdl Bari, 1986; El Fadl, 1997). *Prosopis Africana* ranges in height between 4 to 20 m, its bark is typically grey, rough and extremely scaly. The foliage tends to droop and resembles *Tamarindus indica* (Aradieb) from a distance but is lighter in colour. On the other hand, *P. chilensis* and *P. glandulosa* are small to medium–sized thorny evergreen trees; they rarely transcend 8 m in height, but on a good site with good quality seed, sometimes reach up to 15 m. *Prosopis juliflora* is an evergreen or sometime deciduous tree or shrub depending on the aridity of the site, reaching a height of 12 to 15 m. Due to the tremendous variation within the species, it is difficult to provide a detailed description. It can generally be said to resemble closely *P. chilensis*, though it has a much better tree form (Vogt, 1995).

1.2- Origin and Distribution

The genus *Prosopis* (mesquite) is a legume belonging to the family Fabaceae, and subfamily Mimosaceae. It includes almost 50 species (Duke, 1983). In most tropical and subtropical regions, mesquite has quickly become an important tree genera of the world as a result of deliberate or accidental introductions. Trees of the genus *Prosopis* is wide spread in hot arid and semi-arid zones of Africa, America, Asia and Australia (Burkart, 1976). The native home of prosopis is Argentina in South America (Hasting and Turner, 1965). Only one species, *P. africana* is native to Africa, occurring in the sahelian zone from Senegal to the Sudan, Uganda and Ethiopia. *Prosopis sp.* are extremely drought resistant and therefore have been distributed widely in the regions of arid lands, both within and further than their natural range. *Prosopis* plantations have been established for dune stabilization (Jensen, and Hajej, 2001).

1.3- Growth requirements

1.3.1- Rainfall

Water requirements of *Prosopis sp.* are very wide and generally range between 150 to 700 mm. *Prosopis africana* can grow well in areas with rainfall of 500 mm or more. In areas of low rainfall it may be cultivated by the aid of water harvesting practices. Meanwhile, *P. chilensis* requires 200 to 700 mm and it can be established with irrigation in areas of less rainfall, especially in sandy soils, where it can root deeply. *Prosopis juliflora* is the most tolerant with less initial irrigation requirements than other *Prosopis species*.

1.3.2- Temperature

Temperature requirements of *prosopis sp.* vary from one species to another *P. africana* temperature requirements range between zero-40 °C, while *P. glandulosa* and *P. juliflora* can tolerate very high temperatures, but they are not frost resistant.

1.3.3- Soil type

Prosopis africana grows on clay and sandy soils, and can be found on fallow lands. It is fairly tolerant to most soil types. *Prosopis glandulosa* prefers light sandy soils and can tolerate some salinity. *Prosopis* *juliflora* prefers light sandy soils. It can tolerate rocky, saline, and nutrient–poor soils as long as root growth is not impeded (Vogt, 1995).

1.4- Prosopis weedy nature and problems caused

Various *Prosopis sp.* have different shapes and sizes. They may be found as multi–stemmed shrubby bushes or single stemmed trees with a spreading canopy, ranging from 3 to 15 meters high. Branches are characterized by a crocket structure and the overall impression is of a rather untidy plant, with single branches extending outside the main canopy. On the national significance, mesquite is a weed. It is regarded as one of the worst weeds, because of its invasiveness, potential for spread, environmental and economic impact. The economic impact of mesquite stems from its habit of forming dense, impenetrable thickets, combined with its large thorns, which prevent livestock from accessing pastoral watering holes within them. In pastoral countries mesquite reduces the productivity by taking over grass lands and using valuable water resources. Mesquite may also cause poisoning to livestock by consuming excessive amounts of pods and seeds. Over growing of mesquite may lead to loss of grassland habitat that supports native plants and animals. Mesquite provides safe refuges for feral animals such as pig's bants that lead to land erosion. One of the major problems of mesquite is the invasion of agricultural land, irrigation channels and watercourses. The trees of mesquite are believed to deplete ground water reserves and to reduce growth of neighboring crops (Pasiecznik et al, 2002).

1.5- Utilization

Over the last 20 years, every agriculture and natural resources works have used *prosopis sp.* in one or more of its activities (Field et al, 1996). South Africans believe that the ripped pods make excellent fodder, but the green pods are bitter and valueless. Reddish mesquite gum may used as a substitute for gum Arabic as an adhesive and in the manufacture of gumdrops. Mesquite wood is said to have good acoustical properties (Watt and Breyer, 1962; Allen and Allen, 1981).

In medicine, a ten percent infusion of the leaves shows some antibiotic activity, and chemically fresh pods are harmful to horses. Seeds contain small quantities of saponins. Root and bark contain 1.8% tannin and young leaves contain 0.9% alkaloside (Simpson, 1977).

The main purposes of mesquite introduction in Sudan were to combat desertification; and to provide fuel wood, charcoal, timber, shelterbelt, honey fruit, fodder, agroforestry and medicine. In Bundala National Park, the only wet land in Srilanka, *P. juliflora* introduced to improve saline soils has now become invasive and a threat to native flora and fauna (Algama and Seneviratne, 2000). Elsewhere, however, areas where *Prosopis* trees and shrubs restore degraded land and offer food and shelter to animals, it can be hypothesized that they generally have a beneficial effect on wildlife. The impact on soil biodiversity and fertility may also be assumed to be generally positive, particularly compared with bare land, since vegetation cover reduces erosion by wind and water, stabilizes dunes and increases soil fertility through nitrogen fixation and litter fall. On the other hand, *Prosopis* invasion could theoretically impair the water supply for agricultural crops.

1.6- *Prosopis* in the Sudan

The *prosopis* which is now naturalized in the Sudan was introduced by the Government botanist Massey in 1917, under the name *Prosopis juliflora*. It was brought from two localities: the Egyptian Department of Agriculture at Giza, and South Africa (Broun and Massey, 1929). It is found that there is a considerable, taxonomic confusion about the introduced *Prosopis* in the Sudan (Elsidig et al, 1998). The correct identification has presented difficulties in view of the existence of some closely resembling and allied species (Sahni, 1966). In January 1967, the Royal Botanic Gardens (UK) identified the specimens from Sudan as *Prosopis chilensis* ((Moina) Stuntz)). McMillan (1967) suggested that the material received was not *Prosopis chilensis*, but similar to *Prosopis juliflora*. On the basis of morphological features (twigs, leaves, inflorescence, and spines) of material drawn from various *Prosopis sp*. Abdel Bari (1986) confirmed that the`` "Common mesquite" in the Sudan is *Prosopis chilensis* (((Moina) Stuntz)).

Howerver, the exclusion of *Prosopis juiliflora* from the material examined is seen as a drawback of her identification. Felker (1981) was more confident that *P. juiliflora* ((Swartz) DC)) is the common naturalized mesquite in Sudan (El fadl, 1997). *Prosop*is *africana* ((Gill. and Perr) Taub)) is the only species indigenous to tropical Africa and occurs naturally in the Sudan.

Introduced mesquite into the Sudan were grown in a small plot in Shambat arboretum of Khartoum North; another plot was established near Khartoum airport in 1928. From these two sites, it was found that it grew better near Khartoum on crests of sand dunes. Another plot was established on sand dunes at kilo 5 (southeast of Khartoum) in 1938 and in the same year another plantation on sand dunes near Gordon's tree (Elshagara, southwest of Khartoum) was established but it was later cleared by the sewage-water works. Mesquite was already spreading on all grounds in the vicinity of the village aided by the presence of a large number of goats in the area. There were good results from the plantations grown on eroded slopes near Sennar and elsewhere in the Fung area. Those at Fawwar in the Gazira scheme gave poor yield and were considered to be uneconomic, but others were equally established at Port Sudan on sandy soils with high salt content with initial well-watering for one year. Plantations of Kassala greenbelt and the Gash delta were also successful. Furthermore, on fixed sands with higher rainfall in Darfur and Kordofan the results were disappointing (Elsidig et al, 1998).

Ahmed Elhouri (1986) said that *Prosopis species* were introduced and have played important role in reforestation programme in the Sudan; the genus prosopis reported to combat desertification and to lessen sand movement was suggested to be planted in Khartoum green belt project. The green belt was established in 1962–1964 to control the haboubs (dust tempests) frequenting the main capital and with other objectives. Mesquite then spread in all directions around the belt area. The high population of sheep, goats and cattle especially at Elsalama village helped further in the spread of the new recognizable mesquite (Ballal, 1986; Abdel Bari, 1986). Mesquite provides some benefits in the Sudan i.e provision of fuel wood for daily cooking at the house hold level and use in traditional industries, fodder for livestock, use in building and construction and protection against desert encroachment (Elsidig et al, 1998). The advantages of the species are: easy germination and vigorous growth, high survival rate and nutritious pods (Field and Duke, 1996). The disadvantages of the species include: aggressive growth, the nasty thorns are strong enough to deter most farmers from planting the species on their own land. Wide spreading crown of *P. juliflora* makes it an undesirable candidate for field planting and difficult to manage for wood lots and live fences (Field and Duke, 1996). The problem of mesquite in Sudan is represented in extra cost of land preparation for agricultural production, depletion of range land, adverse effect on biodiversity, negative impact in the pastoral environment in general and the reduction of productivity of land and animals. Advantages and disadvantages evaluations need to be assessed further, and the reaction of the people who are affected by the problem, will be valuable for planning and implementation of an appropriate management and control programme. Again quantifying of the benefits will be useful in working out a control programme and management of the species and to maintain the forest products as substitute for mesquite by indigenous species (Elsidig et al, 1998).

2- *Sorghum bicolor (L.)* Moench

Sorghum belongs to family Poaceae. Somme common names of the species in different languages are: sorghum in English (United States, Australia), durra in Arabic, jowar in Hindu and bachanta in Ethiopia languages.

2.1- Description

It is an annual or short-term perennial plant; culms up to 4 m high or more; panicle 8 to 40 cm long, loose or contracted; sessile spikelets either red or reddish brown, or straw colored or yellowish, sometimes flushed with dark red or reddish brown; grains predominantly red or reddish brown and taste sweet. There are no creeping rhizomes and the mature sessile spikelets are persistent, less than twice as long as wide, not ridged in the middle, 3 – 4.5 mm wide (van Wyk et al, 2000). The bicolor sorghums are characterized by long, clasping glumes at least three-fourths as long as the broadly elliptical grain (van Wyk et al, 2000).

2.2- Distribution

Main center of distribution of cultivated sorghums is in Africa; it has been cultivated in Ethiopia for more than 5000 years. Cultivated sorghums were also possibly developed independently in India and China. Forage sorghums were introduced in the United States of America about 1850. Sorghums are now widely distributed throughout tropics, subtropics (Australia) and warm temperate areas of the world (Duke, 1983).

2.3- Rainfall requirement

Sorghum grows well mostly in an annual rainfall range of 400 to 750 mm. It is cultivated in areas that are too dry for maize. The great advantage of sorghum is that it can become dormant under adverse conditions and can resume growth after relatively severe drought.

Shoot removal lowers its capacity to withstand drought. Early drought stops growth before floral initiation and the plant remains vegetative; it will resume leaf production and flowers when conditions become favorable again for growth. Late drought stops leaf development but not floral initiation (Wilson and Whiteman, 1965). It has adapted itself to a wide range of soils, from the deep sand of the Goz to the heavy black cracking clays of Gedaref, Sudan. Varieties to suit each soil have been selected. Good drainage, however, is necessary. Its deep roots can help extract water from deep sources, though not as deep as *Pennisetum americanum* (Pearl millet). It can tolerate soil pH ranges between pH 5 and 8.5. *Sorghum bicolor* has very low ability to spread naturally. It requires full seedbed preparation for good performance (Wilson and Whiteman, 1965). In developing countries, the seeds are sometimes often planted by hand hoe and covered; the spacing depends on expected rainfall. Small hand drills are available as a first step in mechanization; sophisticated grain and fertilizer drills for precision placement are used in advanced agriculture (Abosuwar, Personal communication, 2005). Sorghum seeds are usually sown at 4 to 5 cm soil depth. The time of sowing is in spring to summer after rainfall and soil temperature should be above 18.5 $^{\circ}$C; at 50 to 60 Kg of seeds/ feddan, depending on soil moisture expectancy, type of sowing and density of stand required. The heavier seeding being for forage production at 70 to 80 Kg of seeds/feddan in areas with rainfall between 675 and 750 mm (Abosuwar, Personal communication, 2005). Seeds of all the *Sorghum species* should be dusted with a combined fungicidal/insecticidal dust before planting. Most sorghum plants take 90 to 120 days to mature. The boot stage is reached at 50 - 60 days and flowering in 60 - 70 days, with full grain maturity in 120 days (Fribourg et al, 2000). Sweet forage sorghum withstands a series of grazing where soil moisture and temperature remain adequate, and the forage or grass sorghum, such as Sudan grass, makes better grazing (Fribourg et al, 2000). The dry green matter yields of sweet sorghums ranges between 3000 - 8000 Kg/feddan according to soil fertility and rainfall (Abosuwar, Personal communication, 2005).

2.4- Uses

Though sorghum is used largely for forage in the U.S.A, it is very important in the world's human diet, with over 300 million people dependent on it (Bukantis, 1980). It is also grown for grain, forage, syrup and sugar, and industrial uses of stems and fibers. Grain sorghum is a staple cereal in hot dry tropics, the threshed grain are ground into flour. Stalks are used for animal feed. It is an important summer fodder where temperatures are high and rainfall insufficient for corn. Most importantly, it is used for silage, green soiling or for hay when grown irrigated in very dry areas. Pearled grains are cooked like rice or ground into flour. Sorghum with large juicy stems contains as much as 10% sucrose and is used in syrup manufacturing, hence sugar can be manufactured from sorghum. Broomcorn is used for making brooms. The seed is used as food, in brewing "kiffir beer", the kiffir corn malt and cornmeal is fermented to make *Leting* (a sour mash), the pith is eaten, and the sweet culm chewed (Watt and Breyer-Brandwijk, 1962). Arubans make porridge and muffins from sorghum meal. Parched seeds are used as coffee substitutes or adulterants (Morton, 1981).

2.4- Fertility

Soil fertility and lime requirements of sorghums are somewhat similar to those of corn, although sorghums are usually more efficient in their use of soil phosphorus and potassium. Balanced fertilization, with ample amounts of nitrogen and adequate phosphorus and potassium is essential to get high yields. At yields of 5 to 7 tons/acre, sorghum crop will remove about 100 lb N, 40 lb P_2O_5 and 180 lb K_2O/acre. Under dry land conditions, it is recommended to add about 60 to 120 lb N/acre; whereas in soils with higher organic matter content smaller amounts of N are required. On sandy soils, it is recommended to apply about 20% of N at planting stage and the remainder within 30 days after emergence. Where sorghum is planted in rows, nitrogen may be side dressed when the crop is 8 to 16 inches tall. Sorghum seeds are sensitive to fertilizer, therefore for row planting, place the fertilizer at 2 inches to the side and at or slightly below seeds depth. For broadcast stands, the fertilizer should be well incorporated into the soil before sowing. A soil pH of 6.0 or higher is adequate for sorghum production (Hughes and Metcalfe, 1972).

Chapter III

Materials and Methods

1- Site description

The experiment was carried out in the nursery of the Faculty of Forestry, University of Khartoum, Shambat (Latitude 15º 39′ *N*, Longitude 32º 30′ *E*). The nursery is located on the eastern bank of the River Nile and thus it is strongly influenced by the prevailing microclimatic conditions due to proximity to the Nile and also by the plantations and cultivation practices around the area. Hence, the site is much cooler and protected from the strong dry winds blowing from the inlands. The experiment was conducted during August – October 2005, when the site receives some showers of rainfall during autumn. The study aimed to examine the effect of mesquite manure compared to NPK fertilizer on the growth and development of *Sorghum bicolor* raised in a sandy soil potting mixture in the nursery.

2- Materials collection

The soil used, consisted of a sandy soil brought from Alrawakeib experimental site, west of Omdurman town. The manure was collected from mesquite trees sprouting abundantly around Shambat area. Leaves and twigs were cut green, air dried and crushed manually into coarse powder with a hand mortar. NPK fertilizer (a complex formula) and

Sorghum bicolor seeds were acquired from Agronomy Department, Faculty of Agriculture, University of Khartoum.

3- Experimental design and layout

The growing media (treatments) were composed as follows:

1/ control: sandy soil without any addition;

2/ M12: sandy soil mixed with 12g/pot of mesquite manure (equivalent to 12 tons/feddan; area of the pot was 227 cm^2);

3/ M24: sandy soil mixed with 24g/pot of mesquite manure (equivalent to 24 tons/feddan; area of the pot was 227cm^2);

4/ M48: sandy soil mixed with 48g/pot of mesquite manure (equivalent to 48 tons/feddan; area of the pot was 227cm^2);

5/ NPK: sandy soil mixed with 270g/pot of complex NPK fertilizer (equivalent to 50 tons/feddan; area of the pot was 227cm^2).

The treatments were placed in unshaded nursery bed and arranged in a split plot design to avoid leakage of materials from different treatments to the others. Each treatment was replicated 5 times; the experimental layout is shown in Plate 1.

4- Monitoring and parameters measured

Sorghum seeds were directly sown in the pots and after germination the seedlings were thinned out and 3 of them were kept per pot. The seedlings were irrigated daily during the first month, then weekly and fortnightly there after. Watering was done by a plastic container equipped with a douche device, every time enough water was poured in until the pots were filled. Weeds were regularly removed whenever they appeared. The height of the seedlings was measured monthly. At appearance of heads, final height was record and the plants were separated into shoot and root. Then, their weights, both wet and dry were measured.

5- Laboratory determinations

5.1- Soil analysis

The soil was first characterized for general properties and then reanalyzed for selected properties after termination of the experiment. Soil samples were air dried and passed through a 2 mm sieve and the following parameters were determined:

1/ particle size distribution was obtained by the modified hydro-peppet method (Day, 1965);

2/ pH was measured by a pH meter (equipped with a combined electrode) in a soil paste (soil: water ratio = 1: 2.5);

3/ exchangeable Ca, Mg, K, Na were extracted by using (0.05 *N*) HCl + (0.025 *N)* H_2SO_4 and analyzed by atomic absorption;

4/ total nitrogen was determined by micro-Kjeldhal method (Pearson, 1970);

5/ phosphorus was determined by spectrophotometer using $NaHCO_3$ method (Chapman and Pratt, 1961).

5.2- Plant analysis

Foliage samples of sorghum and mesquite were oven dried at 60 ^{0}C for 72 hours and were ground into powder (0.5 mm diameter). Ground samples were ashed at 500 ^{0}C, dissolved in conc. HCl and used to determine the following:

1/ total nitrogen by micro-Kjeldhal method (Pearson, 1970);

2/ phosphorus by spectrophotometer using $NaHCO_3$ method (Chapman and Pratt, 1961);

3/ calcium and magnesium were determined by titration with EDTA. (0.5 *N*);

4/ organic carbon was determined by Walkley and Black (1934) method.

Data was analyzed for ANOVA (analysis of variance) using SAS statistical package (SAS Institute Inc., Cary, NC 1997). Significant differences between means were separated by Duncan Multiple Range Test ($p \leq 0.05$).

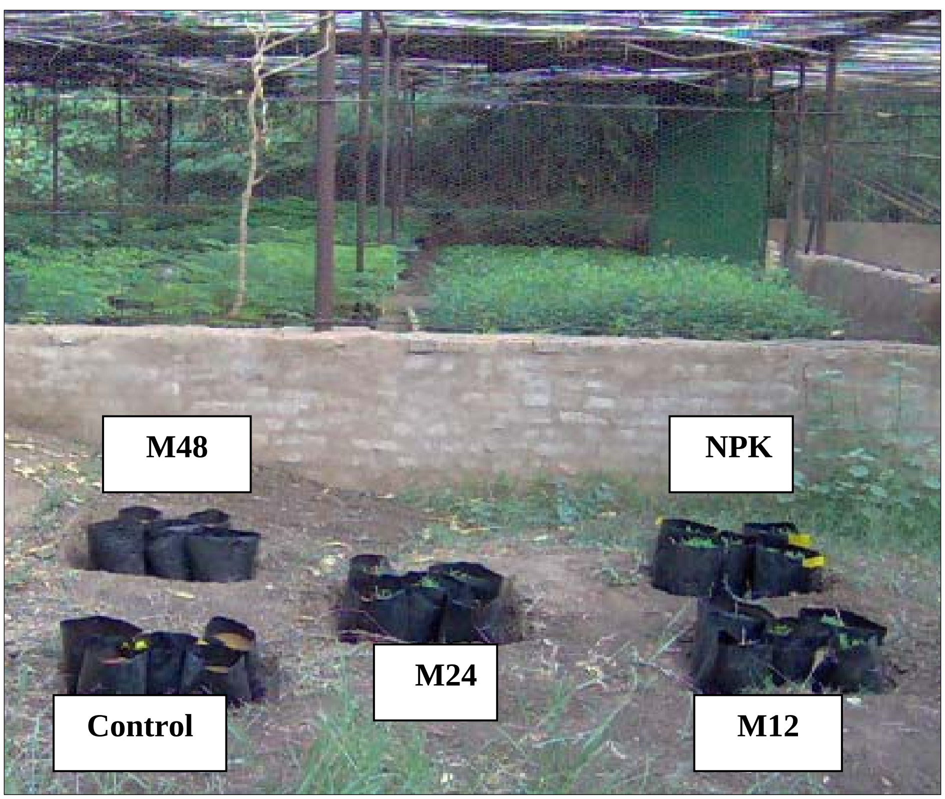

Plate 1: Experimental layout (date: 18 / 8 / 2005)

Chapter IV

Results and Discussion

1.1- Characterization of the soil and mesquite manure

The soil used as growing media was brought from Elrawakieb area 30 Km south west of Omdurman town. The main characteristics of this soil are presented in Table 1. Its texture is sandy, with very little clay and virually no silty fraction and off course it is very porous. It is very poor, especially in the major nutrient elements including available nitrogen and phosphorus.

Assessment of the growing media residues (examined after termination of the experiment) revealed considerable change in the properties of the media as compared to the original sandy soil (Table 1). The media pH has substantially dropped in all the treatments; however, the reduction in the control was moderate. The increase in organic carbon content was very slight in relation to its content in the original soil. C/N ratio values in all the treatments had a similar magnitude and were proportional to changes in organic carbon and nitrogen contents. Substantial increases in the measured nutrient elements were observed in all the treatments as compared to the original studied soil including the control treatment. However, there was no definite pattern of individual nutrient element increase in relation to the ascending amounts of mesquite manure.

Analysis of mesquite manure, used as soil amendment and fertilizer for sorghum, revealed to contain about 3.96% N, 0.71 ppm P, 0.03% K, 10.5% organic carbon and a C/N ratio of about 2.7. This material is rich as compared to values (data) reported in the literature for other leguminous plants (Nimer, 2000; Ahmed and Nimer, 2002).

Table 1: Soil physical and chemical properties before and after amendment with mesquite manure and sowing of *Sorghum bicolor*

Parameters	Primary sandy soil	Control	M12	M24	M48	NPK
pH (paste)	9.3	9.1	7.9	8.0	7.0	8.1
Na (%)	0.019	3.0	0.01	0.3	0.3	0.3
K (%)	0.011	0.3	0.5	0.3	0.3	0.8
Ca (%)	0.001	0.5	0.4	1.2	0.8	1.4
Mg (%)	0.002	1.7	1.4	1.7	1.8	0.8
P (ppm)	0.03	0.35	0.71	0.53	0.89	0.42
N (%)	0.002	0.042	0.7	0.7	0.78	0.56
O.C (%)	0.022	2.52	2.8	2.78	2.98	2.07
C/N	11	53.8	4.0	4.0	3.7	3.7
Clay (%)	9.54					
Silt (%)	0.0					
Sand (%)	90.56					
Texture	Sandy soil					

Control: sandy soil without any amendment; M12: addition of 12g of mesquite manure per pot; M24: addition of 12g of mesquite manure per pot; M48: addition of 12g of mesquite manure per pot; NPK: addition of 270 g of mesquite manure per pot.

1.2- Temporal variation in sorghum height growth

The growth of sorghum height in all treatments proceeded with almost identical pattern from the first week (after germination) to fourth week; the main exception from this pattern was in treatment M48 where sorghum height departed from other treatments from the second week (Figure 1, Table 2 and Plate 2). At this stage (seedlings one month old), the sorghum height did not exceed 50 cm.

In the control, sorghum height grew to about 47 cm in 3 weeks and was very slow between week 3 and week 6 where it did not exceeded 50 cm. Thereafter, height growth went on with very little increment, so that the average sorghum height was less than one meter at the end of 3 months.

Sorghum response to NPK fertilizer (equivalent amount/fed) did not commence until week 6; before that date sorghum height growth in NPK treatment was identical to the control. The effect of NPK fertilizer was rather strong thereafter until week 9, with height increment of about 100 cm in 3 weeks. From week 9 onwards, the weekly height increment was very little and the final sorghum height in this treatment was less than 150 cm. The response of sorghum growth to NPK fertilizer was far weaker than to mesquite manure, so that the difference in final height of sorghum between the NPK fertilizer and the lowest mesquite manure (M12) treatment was more than 120 cm. The response of Sorghum growth to mesquite manure application to sandy soil started to appear since week 4. The low and medium mesquite manure applications (M12 and M24 respectively) induced almost parallel effects on sorghum height growth. Sorghum height increment went steadily upwards week after another ever since week 4. Some disruption occurred in the sorghum height growth in treatment M24 after week 8 so that it slowed down and superimposed with that of treatment M12 in week 9. Another slow down of height growth in this treatment occurred after week 9, which persisted to the end of the monitoring period. The stronger effect on sorghum height was induced by treatment M48, which manifested its influence ever since the second week. Sorghum height growth in this treatment went vigorously upwards with ever widening difference between it and the rest of the treatments. The mean sorghum height in this treatment was 4 meters at the end of week 12 i.e at maturity of the crop.

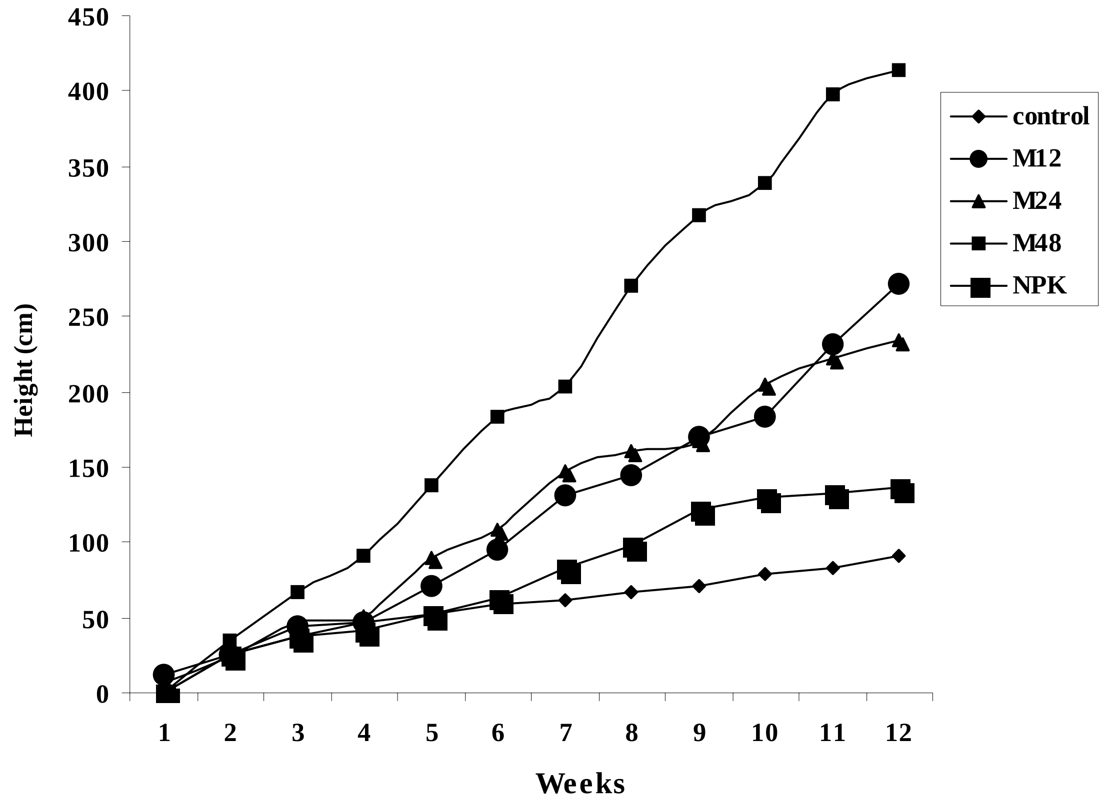

Figure 1: Temporal growth and development of *Sorghum bicolor* seedlings heights (the measurements started from 11/8 and finished in 27/10/2005), Control: sandy soil without any amendment; M12: addition of 12g of mesquite manure per pot; M24: addition of 12g of mesquite manure per pot; M48: addition of 12g of mesquite manure per pot; NPK: addition of 270 g of complex fertilizer per pot.

Table 2: Shoot height increments of *Sorghum bicolor* stalks between weeks

Week intervals	Control	M12	M24	M48	NPK
Week2 - week3	**11**	**19**	**23**	**32**	11
Week3 - week4	**10**	**3**	**4**	**24**	5
Week4 - week5	**5**	**24**	**38**	**47**	11
Week5 - Week 6	**7**	**24**	**20**	**46**	10
Week6 - Week7	**2**	**36**	**38**	**19**	20
Week7 - Week8	**6**	**14**	**14**	**67**	15
Week8 - Week9	**4**	**26**	**6**	**47**	24
Week9 - Week10	**8**	**12**	**37**	**22**	8
Week 10 - Week 11	**5**	**48**	**18**	**59**	**2**
Week 11 - Week 12	**7**	**41**	**13**	**16**	**5**

Week 2 started from 11/8/2005. Control: sandy soil without any amendment; M12: addition of 12g of mesquite manure per pot; M24: addition of 12g of mesquite manure per pot; M48: addition of 12g of mesquite manure per pot; NPK: addition of 270 g of mesquite manure per pot.

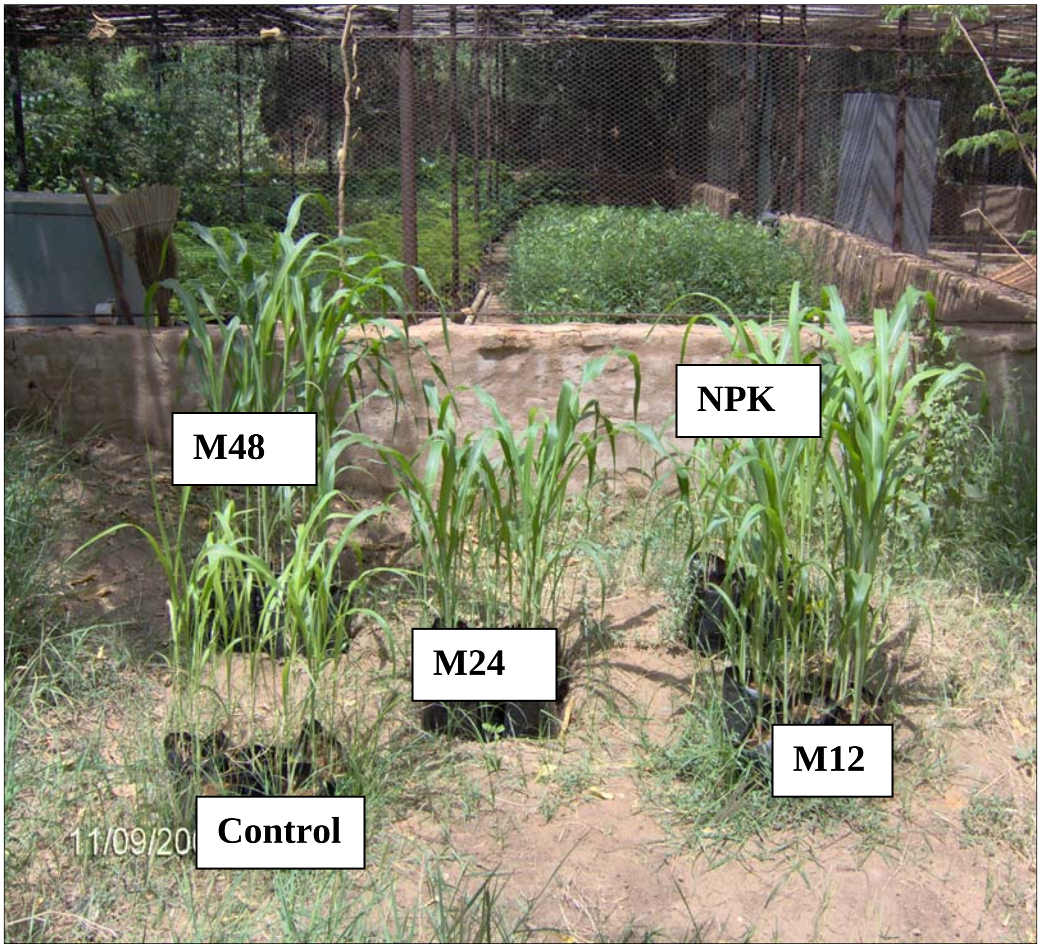

Plate 2: Sorghum bicolor height growth in the different treatments (after one month of sowing 11/ 9/ 2005)

1.3- Final shoots height of sorghum

Results of mean final shoot heights of the treatments are shown in (Table 3). The mean sorghum shoot heights in the treatments were in the following ascending order control < NPK < M24 < M12 < M48. Percent differences of sorghum height growth between the control and the treatments were 51%, 200%, 180%, and 355% for NPK, M12, M24 and M48 respectively. The variation of sorghum height growth was also great between NPK and mesquite manure treatments, in the order of 99%, 86% and 202% for M12, M42 and M48 respectively. The difference was also substantial between mesquite manure treatments, particularly between M12 and M48 (52%) and M24 and M48 (62%). Little difference was observed between M12 and M24 which amounted to 7% only.

The height growth pattern of sorghum in the control and to some extend in NPK treatment was steady, with almost fix height increments between the weeks. The height growth pattern in treatments M12 and M24 was more irregular than in the control with similar increments except after week 10 where there was a strong resumption of sorghum height growth in treatment M12 with bigger increments. The patterns and trends of sorghum height growth outlined in the previous paragraphs are confirmed by the analysis of variance. Accordingly, significant differences ($P \leq 0.0001$) in sorghum height growth were found between all the treatments (Table 3) with the exception of low and medium mesquite manure applications, treatments M12 and M24, which were not significantly different at the specific probability test level.

Table 3: Mean of wet and dry, lengths of shoot and root of *Sorghum bicolor* treated with mesquite manure and NPK fertilizer after 12 weeks of growth

Treatments	Shoot wet weight (g)	Root wet weight (gm)	Shoot/ root ratio	Shoot dry weight (g)	Root dry weight (g)	Shoot/ root ratio
Control	**95c**	**12d**	**8**	**19c**	**4c**	**5**
Mh12	**353b**	**50bc**	**7**	**92b**	**16b**	**6**
Mh24	**232bc**	**64b**	**4**	**57bc**	**16b**	**4**
Mh48	**565a**	**100a**	**6**	**150a**	**42a**	**4**
NPK	**171c**	**30cd**	**6**	**43bc**	**9c**	**5**

Table 3: continued

Treatment	Shoot length (cm)	Root length (cm)	Shoot/Root ratio
Control	**91d**	**31c**	**3**
Mh12	**273b**	**37bc**	**7**
Mh24	**255b**	**41b**	**7**
Mh48	**414a**	**55a**	**8**
NPK	**137c**	**29c**	**5**

Means in the column with the same letter are not significant at $p \leq 0.0001$. Control: sandy soil without any amendment; M12: addition of 12g of mesquite manure per pot; M24: addition of 12g of mesquite manure per pot; M48: addition of 12g of mesquite manure per pot; NPK: addition of Xg of mesquite manure per pot.

The response of sorghum root growth to NPK fertilizer was nil, if not slightly negative, because the average root length in this treatments was smaller than the average length in the control (Table 3). Mesquite manure application has produced positive effect on the sorghum root growth and development. The highest root length was found in the highest manure application, so that the root length in this treatment was more than 1.7 times higher than in the control. Noticeable variations in sorghum root growth were also induced in the moderate mesquite manure treatments as compared to the control. Effectively, the analysis of variance has confirmed the trend of sorghum root growth just outlined. Root length growth in treatment M48 was significantly different ($P \leq 0.0001$) from all treatments including the other mesquite manure trials. The medium and lower manure treatments were not significantly different between them even though there was a significant difference between treatment M12 and the control. The response of NPK fertilizer did not produce significant effect on sorghum height when compared to the control.

Trends of calculated shoot/root ratio were in conformity with the shoot and root length growth outlined previously. The general pattern of these ratios was as following: control < NPK < M12 = M24 < M48. The ratio values showed that root length in the control was about one third of the shoot (Plates 3 and 4), while it was only one eighth of the shoot length in the treatment with the highest mesquite manure application. In other mesquite manure and NPK treatments the shoot/root ratios were in the midway between the extremes in the control and M48 treatment.

Trends of sorghum weight development in the different treatments were very much similar to those discerned for the height, i.e the highest weight was found in treatment M48, medium in treatments M12 and M24 and lowest in NPK and the control (Table 3). Weight increases, vis-à-vis to control were substantial especially in mesquite manure treatments both for shoot and the root. In this respect, the number of times of dry weight increase in the shoot of different treatments as compared to control, were: 7.9 times for M48; 3 times for M24; 4.8 times for M12 and 2.3 times for NPK. For the root comparison, the following values were found: 10.5 times for M48; 4 times for M24; 4 times for M12 and 2.3 times for NPK. As a result, sorghum shoot dry weight of treatment M48 was significantly different ($P \leq 0.0001$) from all the other treatments. Among the other treatments only the sorghum shoot weight of M12 was significantly different from the control. For the sorghum root dry weight, M48 was significantly different from all the other treatments. M24 and M12 were significantly different from the control and NPK, while they were not significantly different between themselves. There was no significant difference also, between the control and NPK treatment. Percent dry matter of sorghum was less than 30 % in all the treatment (Table 3). Its quantities were similar in the mesquite manure treatments and the NPK, whereas there was a difference of 5 to 7 g between the control and the rest of the treatments. The greatest value was for M48 (42%) and the lowest for Mh24, while it oscillated around 30% for M12, NPK and the control. Shoot/root ratios of sorghum dry weights had no definite trend vis-à-vis to the types and amounts of effective material added to treatments. They were 5 for control and NPK; 6 for M12 and only 4 for M24 and M48.

Plate 3: Final harvest of *sorghum bicolor*, showing shoot/root ratio of the control treatment, 28/10/2005

Plate 4: General view of booting stage of *Sorghum bicolor* (treatment M48, 28/10/2005)

Analysis of Sorghum stalks after harvest has shown that there was a substantial effect of mesquite manure on the mineral elements content of the plant (Table 4). Most of the major nutrient elements were enriched by the treatments. The trends of change were as following: for Ca: M48 > M24 = M12 > NPK > Control; for Mg: M48 = M24 > M12 = Control > NPK; for P: all treatments > Control; for N: M48 > M12 > M24 > NPK > Control; for Organic C: all treatments > Control; and for C/N: all treatments < Control.

Table 4: Mineral elements content of *Sorghum bicolor* stalks

parameter	control	M12	M24	M48	NPK
Na (%)	0.005	0.0005	0.0003	0.0005	0.0013
K (%)	0.075	0.015	0.015	0.045	0.023
Ca (%)	0.1	0.7	0.7	1.2	0.7
Mg (%)	1.3	1.3	3.0	1.5	0.35
P (ppm)	0.52	0.70	0.71	0.63	0.72
N (%)	0.02	1.62	1.22	2.52	0.17
Org.C (%)	6.0	10.57	10.58	10.58	10.54
C /N	300	6.52	8.67	4.2	62

Control: sandy soil without any amendment; M12: addition of 12g of mesquite manure per pot; M24: addition of 12g of mesquite manure per pot; M48: addition of 12g of mesquite manure per pot; NPK: addition of 270 g of mesquite manure per pot.

Mesquite manure has induced strong effects on sorghum growth (shoot and root lengths, biomass and foliage mineral contents). The strongest effects coincided with the increasing amounts of mesquite manure added notably the treatment M48, which received an equivalent of 48 tons/feddan and where the mean sorghum height in it attained 4 m at the end of maturity. The effects induced by the NPK fertilizer were moderate as compared to mesquite manure, where sorghum mean height at maturity did not exceed 1.5 m. In addition soil residue properties were considerably improved by the mesquite manure so that, the organic matter and the nutrient elements were increased.

These results indicate that mesquite manure is a very good soil ameliorator and crop fertilizer and the sorghum has positively responded to it. In deed, the amount of nitrogen in the mesquite manure was about 0.5, 1 and 1.9 tons/feddan for M12, M24 and M48 treatments respectively. Mesquite is a leguminous plant with rich nutrient in its foliage and its litter is quickly decomposable that leads to induce positive effects on soil and crops. Aggarwal et al (1976) studied soil fertility changes under a 15 year old stand of *Prosopis species*, in India and showed that soil organic matter, macro and micro nutrients were considerably increased. Geesing et al (2000), in a study in USA, have found that mesquite stands have significantly accumulated nitrogen and organic carbon under their canopy, which was attributed to biological N fixation and litter fall. Also, Herrera-Arreola et al (2007), in a study in Mexico, have found that litter of mesquite and other leguminous trees had a positive effect on the arid and semi-arid ecosystems as they increased soil organic matter and soil N content. Nutrients recycled by leguminous trees have been reported to provide the recommended level of fertilizer for coffee production (Glover and Beer, 1986). Under some forest plantations (neem, prosopis and eucalyptus) in the African Sahel region, maize and sorghum yields out weighed those from the normal bare land fields (Verinumbe, 1987). NAS (1977) outlined the important role of trees, particularly leguminous ones, in improving soil fertility status due to the fact that chemical fertilizers are expensive and the fallow periods are short. Hence, utilizing mesquite manure and other plant residues can help to overcome problems arising from over population, land shortage and deterioration (Shankarnarayan et al, 1987). Definitively, many studies have shown the good attributes of the trees and organic matter on the soil properties and the crop yield, which on the other hand depend on the amounts, quality and conditions of addition (Ahn, 1977; Young, 1986; El Tahir et al, 2004; Wysor, 2005).

Chapter 1V

Conclusion and Recommendations

1- Conclusions

Mesquite manure applied to sorghum bicolor raised in a sandy soil potting mixture and in comparison with NPK fertilizer has induced positive effects both on the sandy soil properties and on sorghum growth parameters:

1- The sandy soil properties have been improved by mesquite manure, noticeably the pH and the nutrient elements (N, P, K, Ca, Mg and Organic Carbon) have greatly increased and the soil structure has been improved as well.

2- Sorghum height, biomass and nutrient contents have increased in all the mesquite manure treatments; the increase in these parameters was proportional to the increasing amounts of manure applied (12, 24 and 48 tons / Feddan).

3- The effects of NPK fertilizer produced on the soil and sorghum growth were moderate in comparison with those induced by mesquite manure and were not significantly different ($P \leq 0.0001$) from the control for most growth parameters studied.

4- This study showed that mesquite can be converted into usefull material instate of constituting a menace to agricultural lands, especially that its residues are rich in nutrients and can improve soil properties and supply crops with mineral elements.

2- Recommendations

1- Further studies are needed to confirm these results and to examine effects of mesquite manure on other crops and in different soil types.

2- Mesquite can be used as an agroforestry tree particularly in arid lands.

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