MASENO UNIVERSITY

FACULTY OF SCIENCE

CHEMISTRY DEPARTMENT

ASSESSMENT OF *ACACIA NILOTICA* IN NITROGEN FIXATION AND NTROGEN AVAILABILITY IN THE LAKE VICTORIA BASIN: A CASE STUDY AT KENDU BAY, RACHUONYO DISTRICT OF WESTERN KENYA

A PROPOSAL SUBMITTED IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL CHEMISTRY

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ABSTRACT

Many soils of sub-Saharan Africa are severely nitrogen deficient but inorganic fertilizers are unaffordable for most subsistence farmers. Rotations and/or intercrop of trees (Acacias) with crops may alleviate nitrogen deficiency through biological N_2 fixation and redistribution of subsoil nitrogen to the surface since Acacia species are known to be nitrogen fixing. The objective of this study is to evaluate the effectiveness of *Acacia nilotica, Acacia senegal and Acacia xanthophloea* to improve degraded lands by fixing nitrogen from the air, extract water and nutrient from deep down in the soil. A comparison will be done on their abilities to conserve moisture in their foliage and effects on Maize *(zea mays L.)* yields. The study will be carried out at Kendu Bay, Rachuonyo District of Western Kenya using completely randomized block design, transplanted Acacia seedlings of 4m by 4m, 3m by 3m and 2m by 2m spacing. Maize leaves will be sampled two times per season while soil sampling will be carried out four times a year at 0-15cm depth to check on the amount of N fixation /N availability resulting from the trees. Maize (zea mays L.) will be planted in rows between the trees and on control plots twice a year. Soil will be analysed for total N, total P and pH determined. The maize yields will be compared against the control to determine the possible variation due to intercropping. Soil pH in water will be determined using a soil to water ratio of 1:2.5 while analysis of total N and P will be done using wet ashing. Wet acid oxidation will be based on Kjeldahl oxidation agent leaving acid solution. Hydrogen peroxide will be added as additional oxidising agent, selenium as a catalyst while lithium sulphate will be added to raise the boiling point of the mixture. The main advantages of this method are that single digestion will be required (for either soil or plant) to bring nearly all the nutrients into solution; no volatilization of metals, N and P takes place and the method is simple and rapid. The amount of total N and P will be determined colorimetrically from the resulting solution. Data obtained will be analysed using Excel and ANOVA series. This study will help smallholder farmers in Sub-Saharan Africa and many other countries in the tropics (Kenya included) to overcome the problem of declining soil fertility resulting from continuous cropping without replenishing soil nutrients thereby improving the peoples livelihood and food security.

Key words: *Acacia nilotica, Acacia senegal, Acacia xanthophloea,l* Nitrogen fixation, Soil rehabilitation, wood.

1.0 INTRODUCTION

Acacia nilotica (L) wild ex Del. (Leguminosae, subfamily mimosoideae) is one of about 135 thorny African acacia species (Fagg and Mugedo, 2005). Variation is considerable with nine subspecies recently recognised, three occurring in the Indian subcontinent and six throughout tropical Africa (Brenan 1983). They are distinguished by the shape and pubescense of pods and the branching habit of the trees. The species is widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa and, in Asia it spreads from Arabia eastwards to India, Burma and Sri Lanka. It has also been cultivated elsewhere including Australia, Cape Verde islands, Indonesia, Iran, Iraq, Nepal, Vietnam and the west Indies. In Africa, the subspecies *indica* is naturalized in Ethiopia, Somalia, Kenya, Tanzania and Angola (Fagg and Mugedo, 2005).

Acacia nilotica tree has achieved worldwide usefulness in land rehabilitation, as it is used extensively in India on degraded alkaline/saline soils, growing on soils up to pH 9, with a soluble salt content below 3%. It is a source of fodder for animals, agroforestry, and wood (producing termite resistant timber especially suitable for railway sleepers). The pods have high levels of dyes and tannins (upto 50%) which are used traditionally for tanning leather and dyeing cotton cloth and fabrics. The secondary metabolites also contribute to its many uses as a powerful astringent, molluscicide, algaecide, and in herbal medicine (Fagg and Mugedo, 2005).

Lake Victoria with a surface area of 68,000 square kilometers and adjoining catchments of at least 155,000 km, is the world's second largest fresh water lake and the largest in the tropics. Lake Victoria is the source of the White Nile, the lifeline of Uganda, Sudan and Egypt. It supports directly or indirectly 30 million people who produce an annual gross economic product of US$3-4 billion. The lake produces about 170,000 tones of fish each year, with thousands of lakeshore residents employed in fishing, fish processing and trade.

Today the lake supports one of the most densely populated and poorest rural populations in the world, with a population density of upto 1200 persons per km in some areas. Incidence of hardcore poverty is between 40% and 50% in parts of Bungoma, Busia and Kericho Districts of Kenya, located in the lake basin.

Colonization of the lake by the water hyacinth and other aquatic weeds is largely due to increased inflow of nutrients in recent decades. There has been a 40% increase in nutrient loading of phosphorous compounds and 10% increase in nitrogen compounds between 1960 and 1995. Bullock et al. (1995) estimated that 50% of the nitrogen input and 56% of phosphorous is due to runoff from agricultural land, 30% of the nitrogen and 30% of phosphorous is due to rural domestic waste, and 10-15% due to urban waste and atmospheric deposition.

Nutrient leaching from agricultural land is not only a major contributor to nutrient loading of the lake but also a major contributor to soil infertility in the adjoining lake basin region. This has led to very expensive farming methods that require heavy reliance on inorganic fertilizers but lead to highly diminished agricultural outputs/returns. Deforestation with little or no tree planting compounds the problem of nutrient leaching through accelerated soil erosion and surface runoffs.

2.0 STATEMENT OF THE PROBLEM

Land degradation in the lake basin is a major concern, not only for the health of the lake, but also for livelihood and food security of its rapidly expanding population. Soils around Lake Victoria are widely degraded and infertile. This leads to poor crop production and requires use of high amounts of inorganic fertilizers to improve crop yields. Most residents around the Lake basin are poor and cannot afford the inorganic fertilizers. It is necessary that cheap methods which reduce soil degradation and improve soil fertility are sought to improve the livelihood of residents around the basin.

3.0 LITERATURE REVIEW

3.1 Description

Acacia nilotica is a medium to large tree that can reach a height of 10 m, with an average of 4-7 m in height. The crown is somewhat flattened or rounded, with a moderate density. The branches have a tendency to drop downwards if the crown is roundish. The bark is blackish grey or dark brown in mature trees and deeply grooved, with longitudinal fissures. The young branches are smooth and grey to brown in colour. The young twigs are covered in short paired hairs, slender, straight spines grow from a single base and sometimes curve barkwards, are upto 80 mm long and whitish but often reddish brown in colour. The leaves are twice compound, elliptical leaflets that can be bottle to bright green in colour. The leaf stalks are very heavy. Very small glands, almost not noticeable with naked eye, can be found at the base of most of the upper pinnae pairs.

The plant bears single to several, bright, golden yellow, globose, scented inflorescences between the leaves. Its flower stalks are hairy. The pods have reddish hairs, becoming dark blakish when mature, deeply constricted between each seed and they do not split open, but break up transversely on the ground into single-seeded segments. The pods are sweetly scented when crushed and contain a sticky fluid (Thomas and Grant, 2004).

Acacia xanthophloea is a tree up to 25m high with straight white thorns arranged in pairs. Bark is yellow. Leaves are compound with 8-17 pair of leaflets. Flowers are in heads, white. Mature pods are yellow- brown, 4-12cm long and slightly constricted between seeds, always in drooping position, never opening but breaking into segments, each with 5-10 pale dark green seeds (Omondi et al, 2004)

Acacia Senegal has a very variable growth form from a multi-stemmed shrub about 2m high to a single-stemmed tree up to 12m tall with hooked prickles arranged in threes, the centralone hooked downwards, the two laterals curved upwards. The barh is yellowish brown or grey-brown.peeling and papery. The leaves are compound with 8-18 pairs of tiny leaflets.Flowers are in spikes, white or cream. Mature pods are grey-brown or red-brown, straight and tapering at both ends, up to 10cm long, splitting open on the tree with 3-5 greenish brown seeds (Omondi et al, 2004)

3.2 Origin and geographic distribution

Acacia nilotica is native to the dry lands of tropical Africa and Western Asia, eastward as India, Myanmar and Sri Lanka. In Africa it occurs from Senegal to Egypt and southwards through eastern Africa to Mozambique and South Africa (Natal) and the Indian Ocean islands. It has been distributed throughout the tropics and became naturalized in many areas, including Cape Verde, Jamaica, Nepal, Indonesia, Vietnam and Australia. It is widely cultivated in the Indian subcontinent (Krishan and Toky, 1995). *Acacia xanthophloea* is widespread and common in places with high ground water, lakesides and riverine between 600-2100m, often on black cotton soils but also on sandy soils. It is very common around lake Naivasha in Kenya. *A. Senegal* is widespread in arid and semi-arid zones between 100-1700m especially on rocky loam or sandy soils with mean annual rainfall of 100-800mm. It is very common in Turkana, samburu, isiolo and Wajir Districts of Kenya (Omondi et al, 2004)

3.3 Uses and Cultural aspects

The wood of *Acacia nilotica* is hard and reddish in colour and most of the browsers eat the leaves. It is used as firewood and for fencing posts. The bark exudes an edible gum and is used in the management of coughs,, eye diseases, tuberculosis, impotence, diarrhea, haemorrhages, toothache, dysentery and gonorrhoea (VanWyk *et al.* (2000). Extracts made from the leaves are used in the treatment of menstrual problems, eye infections sores (specificaly those caused by leprosy), ulcers, indigestion and haemorrhage and its gum can also be used as glue (Sheikh, 1989). The wood of *Acacia xanthophloea* is used for timber, fuelwood, poles and posts. Other uses include fodder (foliage, pods), medicine (bark) bee forage, nitrogen fixing, shade and ornamental (Omondi et al, 2004).

Acacia Senegal is a true multiple-use tree suitable for very dry areas. Its most important economic use is the production of gum Arabic, a high quality gum used as a food stabilizer, glue, starch used for clothing and other industrial applications. The wood makes top quality fuel, as well as good tool handles and posts. Foliage and pods provide good fodder for goats and sheep. Seeds can be dried and eaten as a vegetable. In suitable areas it can be grown with crops like millet and sorghum. As a sand stabilizer in dry areas there are few better species. Young trees require protection from grazing animals as they are highly palatable (Wayne, T., 1985).

3.4 Growth and development

Acacia nilotica is a pioneer species. A deep and extensive root system is formed on dry sites, the tap root developing fast and the laterals, becoming compact and massive with age. On flooded sites however, the root system is largely lateral. *Acacia nilotica* nodulates and fixes nitrogen throughout its natural range and forms mycorrhizal associations with *Glomus* spp. It produces root suckers on rare occasions only. *Acacia nilotica* flowers at a relatively young age, around 3-4 years old under ideal conditions. Flowering is prolific and occurs on current-season growth mainly during the rainy season. If adequate moisture is available flowering can occur a number of times during the year (Burkill, 1995). *Acacia xanthophloea* seeds matures within 4-6 months and pollination is by insects.

3.5 Ecology

Acacia nilotica is a tropical species, growing where average annual temperatures range from 15-28°C, being frost sensitive when young and withstanding daily maximum temperatures of 50°C. It grows from sea-level to over 2000 m altitude. *Acacia nilotica* prefers dry conditions, with an annual rainfall of 100-2300 mm, however the extremes are only found under irrigation or where planted outside its natural range, e.g in south –east Asia. It occurs in both unimodal and bimodal rainfall regions with summer or winter regimes. Depending on the subspecies, it will tolerate both drought and flooded conditions for several months. The subspp. *nilotica* and *tomentosa* are restricted to riverine habitats and seasonally flooded areas on alluvial clay soils. In the Indian subcontinent, subsp. *Indica* occurs in dry forests at low altitudes, usually on alluvial soils subject to flooding or on black cotton soils. It is now widely planted on farms throughout the plains and will also grow on saline, sodic or alkaline soils and on soils with calcareous pans (Fagg, *et al.* 1997).

3.6 Propagating and planting

Acacia nilotica can be easily propagated from seed. Trees produce seed in abundance from around 5-7 years old. Seeds can be extracted from the pods while seeds ejected by sheep during rumination or those from cattle and goats droppings may be collected. The latter seeds germinate easily due to fermentation and moistening (Mandal, *et al.* (1994). Germination starts 1-3 weeks after sowing and is mostly complete in one month. Pre-sowing treatment is required once seed exhibits dormancy as the seed coat is very hard.

3.7 Management

Plantations of *Acacia nilotica* for timber, tannin or gum production require regular weeding and thinning to maintain maximum growth. Along the Blue Nile in Sudan, thinning begins from 4-5 years and continues in 3-year cycles. An ideal stocking density at 30 years is 100 trees/ha for 28 m tall trees and 400 trees/ha for 14 m tall ones (Singh, 1982). In old stands in Sudan, used for fuel wood extraction there is evidence of adequate natural thinning and additional thinning seems not justified.

4.0 JUSTIFICATION

In recent years, the most urgent problems around Lake Victoria region are directly or indirectly due to the invasion by water hyacinth on fishery, water transport and health. Fishermen are forced to engage in increasingly desperate and unsustainable use of natural resources on the land. These include exploitation of fragile areas such as wetlands, and clearing of vital forests to open up new arable lands and to gather firewood, thereby intensifying erosion. The destruction of the basins wetlands to create space for cultivation and grazing of cattle has in turn led to loss of biodiversity and to decreased agricultural returns and filtering effect on the water entering the lake via watercourses. By introducing multipurpose plant species these problems can be overcome.

Although high yields are generally associated with high organic matter content in low external input agriculture, the nitrogen and carbon components of the organic matter are difficult to interpret. The levels of N, in the plant-available NH_4 and NO_3 forms fluctuate during the cropping season and are dependent on factors such as soil moisture (rainfall pattern), cropping history, litter inputs and microbial activity. (Okalebo et al., 1993)Phosphorous deficiencies are also known to significantly reduce biological nitrogen fixation capacities in most legume crop/trees. Therefore, this study will examine the relationship and check on the influence of phosphorous in nitrogen availability of the soil (Ndufa et al., 1999)

Based on our previous investigations on geographical distribution of trees and their uses in Lake Victoria Basin, this study proposes the introduction, management and utilization of *Acacia nilotica* as part of our concerted effort to improve soil fertility because of its nitrogen fixing capability and economic exploitation among its many other uses.

Some of the envisaged common intervention strategies towards solving the problems of Lake Victoria Basin are as follows:

1. Reduce nutrient outflow from agricultural lands by planting *Acacia nilotica*, which helps to fix nitrogen to the soil thereby reducing the application of fertilizers.

2. Assist the affected shoreline communities to better cope with the new situation, in order to gain experience on viable interventions that enable affected fishing communities to take up broader land based activities for income generating by planting this multipurpose tree species *Acacia nilotica* for future production of gums, tannins, medicine, timber, fodder and firewood.

Acacia nilotica is truly a multipurpose tree which can be widely used as soil conditioner, timber, and source of fodder, tannin and gum, herbal medicines, shade and fuel tree by the local community. The species is easy to propagate from seed, fast growing, nitrogen fixing, tolerant to poor soils, adaptable to both arid conditions and wetland alkaline/saline conditions.

5.0 HYPOTHESES

1. Acacias can grow around Kendu Bay
2. Acacia will improve soil fertility
3. Acacia will increase maize yields in the region
4. Acacia grown around Lake Victoria basin will produce economic amounts of gums, tannins, medicines, timber, fodder and fuelwood.

6.0 OBJECTIVES

6.1 Overall Objective

To evaluate the effectiveness of *Acacia nilotica* in nitrogen fixation/ availability in the Lake Victoria Basin

6.2 Specific Objectives

1. To determine the extent at which *Acacia nilotica, Acacia Senegal* and *Acacia xanthophloea* fix nitrogen over time

2. To determine the effective spacement of *A. nilotica* for maximum nitrogen fixation/availability

3. To determine the moisture content of different spacement of *Acacias* for better maize growth

4. To check the effect of P on nitrogen fixation/availability of *Acacias*

5. Determine the pH of the soils with time

7.0 MATERIALS AND METHODS

7.1 Study Area

This study will be carried out on degraded soils in Nyanza Province:- Kendu Bay location of Rachuonyo District in Western Kenya.

7.1.1 Experimental Design and Sampling Methods

It is a randomized complete block design replicated three times. Three species are being evaluated: *Acacia nilotica, Acacia Senegal* and *Acacia xanthophloea.* Unfertilized continuous maize is included as control and plots are 6m x 6m.

Specific treatments will be as fallows:

Treatments
Acacia nilotica + maize, 2m x 2m spacing
Acacia nilotica + maize, 3m x 3m spacing
Acacia nilotica + maize, 4m x 4m spacing
Maize
Acacia senegal + maize, 2m x 2m
Acacia xanthophloea + maize, 2m x 2m

Weeding and thinning will be done regularly to maintain maximum growth. Thinning will begin from 4-5 years and continue in 3- year cycles. After sowing 2-3 weeding are sufficient to control weed growth. Soil sampling will be done four times a year at a depth of 0-15cm to check on the nitrogen fixing capacities of the trees and check if there will be any variations with site conditions. Maize will be planted at 70cm by 30cm in rows between the trees and on control plots twice a year at the beginning of the long and short rains.

In addition, the plant and soil samples will be analyzed for phosphorus, moisture content of the soil and pH determination will also be carried out to check for any influence on nitrogen availability and uptake by plants.

The maize yields from the experimental site will be compared against the control to determine the increase in yields.

7.1.2 Sources of Seeds and seed Scarification

Acacia nilotica seeds will be obtained from Kenya Forestry Research Institute, KEFRI, Seed Centre in Nairobi. The seeds will be pre-treated by boiling in water for 10-15 seconds and then soaked for 24 hours in cold water before sowing in a seed- bed. The seedlings will then be transplanted in polytubes to reach a height of 25-30cm in 4 months (Mandal, *et al.* 1994).

7.1.3 Sample storage

The samples will be carried in sugar bags to the Regional Research Centre, Maseno and air dried, gently crushed, sieving through 2 mm sieve before storing in air tight bottles.

7.2 Soil pH in water

7.2.1 Background

This is a standard method and uses a soil: water ratio of 1: 2.5. Analyses are conducted in batches of 33 with 30 soil samples, 2 repeated samples and 1 standard soil sample (Okalebo, *et al*, 1993).

7.3 Analysis of Total Nitrogen and Phosphorus in plants and soils

7.3.1 Background

Analysis of total nutrients requires complete oxidation of organic matter. This is accomplished through dry ashing or acid/alkaline digestion of the material in question. Wet acid oxidation is based on Kjeldahl oxidation agent to leave sulphuric acid solution. Hydrogen peroxide is added as an additional oxidising agent, selenium is used as a catalyst while lithium sulphate is added to raise the boiling point of the mixture. The main advantages of this method are that single digestion is required (for either soil or plant) to bring nearly all nutrients into solution; no volatilization of metals, N and P takes place and the method is simple and rapid.

The procedure is fast, accurate and reproducible.

7.3.2 Determination of Total Nitrogen

Acid digestion of the plant/soil material will be followed by colorimetry. The choice is dependent on local facilities; but colorimetry procedures are more rapid (Anderson and Ingram, 1989).

7.3.3 Determination of Phosphorus

The resultant solution from the digestion procedure is strongly acid. Colorimetric procedures for P estimates in such solutions will be used (Okalebo, 1985).

8.0 EXPECTED OUTPUTS

1. Created awareness on the importance of *Acacia nilotica, acacia Senegal* and *acacia xanthophloea* leading to planting of more of the tree for reclaiming nitrogen deficient soils in the region and for their economic exploitation.

2. Demonstration plots on on-farms

3. Local capacity for ex-situ conservation and sustainable commercial and industrial utilization of *Acacia nilotica, Acacia senegal* and *acacia xanthophloea.*

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10.0 WORK PLAN

Activity	S	O	N	D	J	F	M	A	M	J	J	A
Survey of the sites	x	X										
Seed collection and pre-testing	x	X										
Nursery establishment / raising of Seedlings		X	x									
Site characterization		X	x									
Land preparation		X	x									
Planting			x	x								
Monitoring/Sampling					x	x	x	x	x	x	x	X
Reporting						x			x			X

11.0 BUDGET

Activity	Period	Cost	Day	Rate	Total
Survey	Sept-Oct	Student	6	2200	13200
			6	1800	10800
		Tech	6	1800	10800
		Driver			8000
		Fuel			
Seed collection/ Pre-testing	Sept-Oct				10000
Nursery operations	Oct-Nov	Polythene bags			2000
					2000
		Soil collection			1000
		Manure			8000
		Labour			5000
Land preparation/ Site characterization	Oct-Nov	Tech	6		10800
		Driver	6		10800
		Fuel			8000
		Ploughing			9000
		Labour			4500
Planting	Nov-Dec	Student	6	2200	13200
		Tech	6	1800	10800
		Driver	6	1800	10800
		Fuel			8000

		Labour			4500
Monitoring/Sampling	Jan-Sept	Student Tech Driver Fuel	3 3 3	2200 1800 1800	6600 5400 5400 8000
Chemical Analyses	Nov-Aug				200000
Supervisors visit					50000
Grand total					436600