CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

The pressure from a rapidly increasing population in Africa is causing an increase in demand for land used for settlement and food production. Traditional farming methods such as a ten year natural vegetation fallow followed by slash and burn practices have been replaced by the use of fertilizers and chemicals because of the unavailability of arable land that can be left fallow for long periods (Kamara *et al.* 1993). These soil amendment methods are expensive for African farmers and are non-sustainable and environmentally unfriendly (Kumwenda *et al.* 1995; Parks & Seaton 1996). Over-utilisation of agricultural land is leading to a decline in soil fertility and an overall decline in environmental quality.

Solutions for soil fertility problems rely on improvement of soil chemical and physical properties, but often the role of biological properties is overlooked (Lee 1994). The soil biota has evolved and is widely established to govern soil processes that naturally maintain soil fertility such as soil nutrient cycling and soil aggregate stability processes both of which are influenced positively by fungi (Gupta *et al.* 1990; Hawksworth 1991; Kennedy & Smith 1995). Application of fertilizers and pesticides greatly alter the soil environment under which these microbes function. Their efficiency may thus be altered, possibly leading to a total elimination of vital bio-components before their potential is realized. The effects of the application of fertilizers and chemicals are a short-term solution and they do not accommodate the living nature of soil that constantly requires the replenishment of organic input to sustain life in it.

Awareness in environmental degradation by conventional agricultural methods has ushered in more environmentally friendly biologically based farming practices (Bull 1996; Parks & Seaton 1996). The use of biological methods to improve soil fertility includes farming practices that use less fertilizer and chemical inputs. Agroforestry is one such practice with multiple benefits to the soil, the environment and the farmer (Young 1997). Agroforestry, the deliberate integration of trees or shrubs into crop and livestock production systems (Young 1997; Sanchez 1995) has multiple benefits. Trees are known to have a different impact on soil properties than annual crop because of their longer residence time, larger biomass accumulation and longer lasting more extensive root system (Sanchez *et al.* 1996). The ability to improve soil fertility by acquisition of nutrients and improving soil structure has been verified with these methods (Young 1997; Sanchez *et al.* 1997). Few studies have, however, been undertaken on the effects of these practices on soil biota, particularly in Africa.

A healthy soil maintains a balance of a wide range of organisms that have mutual benefit for the system that supports them. Soil organisms maintain soil pH with production of organic acids, fixing of atmospheric nitrogen and providing for the enzymatic breakdown of the more complex carbon molecules (Atlas & Bartha 1986; Paul & Clark 1989). Alterations of the soil ecosystem may result in changes in populations and functions of the soil biota.

The soil biota is considered a long-term investment in sustainable systems and may not have a direct and immediate impact on the soil quality. However, monitoring changes in distribution and quantity of soil organisms may serve as indicators of directional changes in processes such as recycling and solubilization of mineral nutrients, organic acids which are plant growth promoters and disappearance of organisms antagonistic to potential pathogens. There is a wide range of soil organisms known for decades as vital in natural soil nutrient cycling and homeostasis maintenance for good growing conditions. Among these organisms is the Arbuscular Mycorrhizal Fungi (AMF) in the phylum *Glomeromycota* C. Walker & Schuessler, phylum nov. (Shüßler *et al.* 2001), that form a mutually beneficial association with plants and are keystone to soil processes (Harley & Smith 1983; Hawksworth 1991; Power & Mills 1995; Bull 1996). The interface between the soil and plants created by these fungi is affected by both plant and soil conditions.

The AMF are globally widespread and associate with most plant species (Harley & Smith 1983). The potential of AMF fungi in agriculture and forestry is well established and its potential for Africa has been postulated (Sanginga *et al.* 1992; Sieverding 1990). Most parts of Africa still remain unexplored and hence AMF communities are not known. The use of AMF is hampered by inadequate information on the diversity of species, global and local distribution and conditions of survival and effective functioning.

The AMF symbiosis in agroforestry is a reasonable point to initiate the evaluation of mycorrhizal functioning in a system that approaches the management ideal of low input sustainable agriculture. Agroforestry trees have great potential to improve soil properties in association with mycorrhizal fungi. This, however, demands knowledge of the best conditions required for survival of the mycorrhizal symbiosis. Hence the type of fungi that thrives best under agroforestry conditions and their relationship with agroforestry trees and crops will form a basis for the development of utilisation strategy. Biologically based sustainable farming systems such as agroforestry widely used in resource-poor countries of Africa, Asia and South America (ICRAF 1996), may enhance diversity of AMF. Trees primarily enhance soil fertility through processes of nutrient capture, improving nutrient levels and protecting soil from soil erosion and are recorded to improve maize yield in highly nutrient depleted soils of Malawi (Maghembe & Prinns 1994). Agroforestry trees improve soil nutrients, particularly nitrogen (Kwesiga & Coe 1994; Ikerra *et al.* 1999) and other nutrients such as phosphorus and potassium (Mwiinga *et al.* 1994) through incorporation of leaf biomass. Trees, through the root system and organic inputs, improve soil physical properties by enhancing structure, porosity, permeability and water holding capacity (Yamoah *et al.* 1986).

Studies relating to soil organisms in agroforestry systems have focused on nitrogen fixing bacteria, as nitrogen is the nutrient required in large quantities for maize production. Agroforestry was reported to improve soil nitrogen levels (Kwesiga & Coe 1994). It was also observed that non-nodulating leguminous species accumulated high nitrogen levels (Ladha *et al.* 1993; Tomlinson *et al.* 1995) with mechanism speculated to be mycorrhizal.

The root system is an important organ of the plant that supports the shoot, enhances nutrient replenishment, nutrient uptake, aggregate formation and it forms 30–50 % of the plant biomass (Young 1997). Associations with organisms, particularly AMF, may enhance the efficiency of the root system and maximize root functions. Nutrient capture may be enhanced by a highly mycelial root system that would provide a large surface area and aggregate stability may also be improved by an extensive mycelial network (Sutton & Sheppard 1976). Root-knot nematode disease in *Sesbania sesban* could be reduced by mycorrhizal symbiosis.

Incorporation of leaf biomass from agroforestry trees into the system may provide favourable conditions and support a high diversity of AMF. Agroforestry trees may differ in their effects on fungal species diversity and occurrence. Agroforestry practice was proved to be suitable for the highly nutrient depleted soils of southern Malawi that occasionally experience severe droughts and mild floods (Maghembe & Prinns 1994).

Studies on AMF symbiosis, particularly the diversity and occurrence of the indigenous communities in agroforestry systems, may form the initial basis for utilization. The use of AMF in agroforestry will depend on soil and plant conditions favourable for survival of the various fungal species. How the fungal species respond to seasonal changes may establish the best way to conserve and maintain a high AMF fungal diversity under severe conditions such as drought. The general and most significant test of the agroforestry systems is how it compares with the most intensive and purely organic management systems.

Commercial production and use of AMF inoculum will depend upon knowledge of species diversity, distribution and adaptation. Johnson and Menge (1982) saw the use of mycorrhiza as an alternative to fertilizer and hence a way of saving money. The mycorrhizal symbiosis to date is unable to substitute for fertilizers, though there is increasing interest in the use of mycorrhizal fungi. This is evident in the increase in numbers of companies producing commercial formulations of AMF such as Vaminoc (Microbiodiv. Agricultural Genetics Company, Royston, England), Dr. Kinkon (Idemitsu Koskan Co. Ltd, Tokyo Japan), Mycorise (Premier Tech., cp 3500, Quebec, Canada) and Biovam (Washington, United States of America). Gaur *et al.* (1998), however, observed success with the formulation Mycorise and a mixed indigenous AMF culture on Capsicum and Polianthes species but not with Dr. Kinkon or Vaminoc. There is therefore need to study indigenous fungal communities before use of exotic species is recommended and also explore the prospects of developing commercial formulations in a more systematic and orderly way. The use of indigenous fungal communities will also eliminate the dangers of introducing root pathogens from exotic inoculum and the exotic species becoming hazardous.

The aim of the study is to establish the taxonomic diversity of AMF in an agroforestry system of Malawi and determine whether changes in farming systems, soil conditions and season will affect AMF species as well as plant growth.

1.2 OBJECTIVES

1. To establish the taxonomic groups of AMF from agroforestry systems of Malawi.
2. To determine species and ecological diversity of AMF fungi in *Gliricidia sepium* /maize intercrop and maize monocrop systems in the wet and dry season, and at four fertility levels.

3. To determine species and ecological diversity of AMF in *Sesbania sesban*/maize and *S macrantha*/maize intercrop and maize monocrop systems in the wet and dry season, and at four fertility levels.
4. To determine the effects of selected AMF species from the same site on growth of maize, *G. sepium, S. sesban* and *S. macrantha*.