

A Review on: The Effect of Agro Forestry Trees on Minimizing Infestation of *Striga hermonthica* Through the Enhancement of Arbuscular mycorrhiza (AM) with Sorghum in the Northern Part of Ethiopia

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Abstract

Sorghum is one of the major food grain crops in Ethiopia, especially in the northern part of the country. The production and productivity of sorghum is affected by the root hemi parasite *Striga hermonthica* (Del.) Benth. (Orobanchaceae). In Ethiopia it is limited integrated control measure have been carried out to combat *Striga*. Reasons for the limited success in *Striga* control include prolific seed production, monocropping, close coupling of its life cycle to that of its host, and the fact that effective control methods are not within the reach of farmers practicing subsistence agriculture (Oswald A.2005). Sustainable management systems targeting *Striga* management on cereals in general or sorghum in particular might benefit from managing this symbiotic interaction. Agro forestry trees have the capacity to enhance AM and symbiotic relationship between sorghum can blocks for *Striga hermonthica* so as not to get any communication with its host.

Keywords: AM symbiotic, *Striga hermonthica*

1. Introduction

Agroforestry is a land use system and practice in which forest trees, livestock, and arable land are integrated on the same unit of land and managed to give yield on a sustainable basis either simultaneously or sequentially. The integration can be linear, mixed, or even in blocks in an arrangement based on specific objectives and appropriate technology required for a particular place. Several traditional systems exist in Ethiopia, and there are new technologies started by several institutions at a national level across different land use systems. (Jiru.1990.) Growing *Faidherbia albida* as a permanent tree crop, on farmlands with cereals, vegetables and coffee underneath or in between, is an indigenous agro forestry system in the highlands of Eastern Ethiopia. The results of an investigation in to the effects of the presence of *F. albida* on farmlands on the yield of maize (*Zea mays L.*) and sorghum (*Sorghum bicolor L.Moench*) statistically significant increase in crops yields by 56% on average was found for the crops under the tree canopies compared to those away from the trees. In Ethiopia acute household energy and feed demands have caused severe environmental and socio-economic threats. Multipurpose tree species have considerable role in addressing such multifaceted demands in the mixed crop-livestock production systems. Studies on AM fungi symbiosis, particularly the diversity and occurrence of the indigenous communities in agroforestry systems, may form the initial basis for utilization. Agroforestry trees may differ in their effects on fungal species diversity and occurrence (Mnyazi, 2004). Incorporation of leaf biomass from agroforestry trees into the system may provide favorable conditions and support a highly diversity of AM fungi and also investigated the vertical distribution of AM fungal spores under agroforestry. AM fungal spores were found in the deep soil layers of agroforestry systems than in monocultural coffee plantation soils. In agricultural field of standing farm trees, spore abundance found to be higher under the tree canopy than in monoculture crops. Pande and Tarafdar, (2003) reported spore densities of field standing neem (*Azadirachta indica L.*) trees in agroforestry systems in different agricultural zones of Rajasthan, Similarly, Zebene and Hultén, (2002) also reported, higher number of spores under the canopy of *Cordia africana* and *Millettia ferruginea* grown in sorghum fields. In general agroforestry trees plays a land mark role in creating a medium for AM. Symbiosis relationship between AM and Sorghum which is created as a result of Agro forestry tree is very common, and AM has an effect on germination, attachment and subsequent growth and development of *Striga hermonthica*. Reviewing the indirect effect of agro forestry tree on *Striga* (the effect of AM on growth and development *Striga hermonthica*) is the main aim of this paper.

2. Agro forestry trees, sorghum and Fungi associations

2.1 AM and plant association

Mycorrhiza is a mutualistic symbiosis between plant and fungus localized in a root or (root-like structure) in which energy moves primarily from plant to fungus and inorganic resources move from fungus to plant (Allen, 1991). Mycorrhizal associations vary widely in form and function. In the tropics, the two most common associations are the arbuscular endomycorrhizas (AM) formed by Zygomycete fungi, and the ectomycorrhizas (ECM) formed by Basidiomycetes, Ascomycetes, and a few Zygomycetes (Dell, 2002). Ectomycorrhizae (EM) forms a thick sheath of fungal hyphae around the plant roots, making an obvious change in the morphology of

the root (Wiedenhoef and Hopkins, 2006). The diagnostic feature is the presence of hyphae between root cortical cells producing a netlike structure called the Hartig net (Haselwandter and Bowen, 1996), and many ectomycorrhizae also have a sheath, or mantle, of fungal tissue that may completely cover the absorbing root (usually the fine feeder roots). This mantle can vary widely in thickness, color, and texture depending on the particular plant-fungus combination and the mantle increases the surface area of absorbing roots and often affects fine-root morphology, resulting in root bifurcation and clustering, contiguous with the mantle are hyphal strands that extend into the soil. Normally the fungus does not penetrate the endodermis or the stele. Under EM association lack root hairs and the outer cortical cells are radially elongated, suggesting a hormone interaction (Haselwandter and Bowen, 1996). The association of EM is mainly with trees not with agricultural crops. It is more important in multipurpose woodlots and taungya agroforestry practice. Arbuscular mycorrhizas (AM) fungi or glomeromycotan mycorrhiza, are the most widely spread and common root-fungus associations (Brundrett, 2004). They are by far the most common mycorrhiza type, infecting the great majority (about 80%) of higher plants (Smith and Read, 1997). AM fungi occur ubiquitously due to its great potential of ecological adaptation (Kleikamp, 2002). Morphologically, these fungi have a network of hyphae that grow within the roots of plants and extend out into the soil. Unlike the ectomycorrhizal fungi, AM fungi actually penetrate the walls of root cells and form intracellular structures. AM fungi develop a highly branched arbuscule, acacia canopy shaped within root cortical cells, and the fungus initially grows between cortical cells, but soon penetrates the host cell wall and grows within the cell. Vesicles are like small bags or sacs sequestered within or between plant cells and are implicated in energy storage and possibly as propagules for the fungus, whereas arbuscules are small tree-like collections of branched hyphae that occur within the plant cells (Wiedenhoef and Hopkins, 2006). The original taxonomy of the AM fungi was based on the morphology of the large soil-borne spores which were found near colonized plant host's roots (Simon *et al.*, 1993). A number of studies have shown that agriculture reduces the diversity of the AM fungi community (Daniell *et al.*, 2001; Oehl *et al.*, 2003). This has been attributed to physical disturbance from tilling (Kabir *et al.*, 1997) the effects of supplemental fertilizers (Linderman and Davis, 2004) and the use of fungicides and soil fumigants (Menge, 1982), all of which reduce the abundance and or diversity of AM fungi. Generally low input and low till agricultural systems have a higher abundance and diversity of AM fungi than their traditional counterparts (Douds and Millner, 1999; Galvez *et al.*, 2001). Similarly, returning crop residues to soil might stimulate an increased spore population, and application of farmyard manure increases densities of AM fungal spores, although it depends on soil types. Organically farmed system had a similar AM fungal diversity to nearby native grassland (Oehl *et al.*, 2003). It has also been shown that the presence of agricultural weeds can increase the abundance of beneficial AM fungi in the fields (Vatovec *et al.*, 2005). High spore and AM populations found during the dry season, under low input agriculture, low tillage agricultural systems and plant phenology (Guadarrama, 1999; Douds and Millner 1999). In the natural forests, high abundance and diversity of AM fungi found, where there was no disturbance on the vegetation cover. Tropical rain forests display high species diversity and complex community structure, and they are a major distribution area for AMF in the world (Zhao *et al.*, 2001) and in the dry soil in Afromontane moist forest ecosystem of 14 coffee shade tree species.

2.2 AM Root Colonization

AM fungi exist in the soil as spore or as vegetative propagules in root fragments. Species of AM fungi have been reported to lack host specificity as a consequence of this a given fungal propagules obtained from an annual plant can also readily establish on a perennial plants. Similarly a given plant root system can be infected by different group of AM fungal species. Resting spore of the fungus, germinating or extra radical hyphae in the soil or hyphae associated with root fragments are infective propagules where the fungal development can start (Brundrett *et al.*, 1996). Usually association starts when the soil hyphae contact a root of potential host. Penetration takes place between the epidermal cell and often forms an appressorium (Brundrett *et al.*, 1996). The successful establishment of mycorrhiza on host root depends on the interaction between the symbiont and environmental factors such as soil moisture, pH and soil fertility. Manipulation of agricultural systems to favor AM fungi colonization must occur only if there is clear evidence that AM fungi make a positive contribution to yield or are vital for maintenance of ecosystem health and sustainability (Ryan *et al.*, 2002). Mycorrhizal dependency of a given plant can be altered by many variables such as soil type, soil phosphorus content, mycorrhizal species etc. (Menge *et al.*, 1987). As soil conditions profoundly affect root growth and sometimes root hair production in the same species, it is highly likely that the extent of the mycorrhizal response will differ from soil to soil independent of soil phosphate status (Haselwandter and Bowen, 1996). It is widely accepted that plants with highly branched root system (Gramineae) are less mycotrophic (less dependent on the fungi for normal growth) than those with coarser roots (e.g. cassava, onion) (Dodd, 2000). Root branching determines plant dependence on the symbiosis. Over 10% of plants (including complete plant families e.g. Chenopodiaceae and Brassicaceae) are non-mycorrhizal and these plants compensate by developing extensively branching root system architectures (Dodd, 2000). They include many of the crops used in Europe today e.g. oil

seed rape (canola). Root characteristics have been little studied with species used in agro forestry but many tree species do have low rooting intensities and poorly developed root hairs and respond well to mycorrhizal infection over a wide range of soil phosphate (Haselwandter and Bowen, 1996). Jasper *et al.* (1989a) observed relatively coarse rooting systems and few root hairs in *Acacia concurrens* and *A. saligna*, attributing their large mycorrhizal responses to this. The extent of mycorrhiza infection in root systems is also known to be influenced by environmental conditions; the most important being the age of the plants, the level of phosphate (P) in the soil relative to the requirements of the plant and the capacity of the population of mycorrhiza propagules in the soil to form mycorrhiza, light, temperature and others (Smith and Read, 1997; Smith, 2003; Azcón and Ocampo, 1981). Nevertheless, mycorrhizal infection can also be related with plant factors such as nutrient content in the root exudates; this parameter seems to be regulated by P concentration in the root (Azcón and Ocampo, 1981). Zebene and Hultén, (2002) reported, different levels of root colonization in the roots of *Cordia africana* and *Milletia ferruginea* grown in enset, coffee-enset and maize fields. Agriculturally adapted AM fungi have been shown to be slower to infect, faster to sporulate and to produce fewer arbuscles (Johnson, 1993;). Tillage disturbs the hyphal network, which delays the AM fungi infectivity rate on plant roots in the coming season (Friberg, 2001). The use of native mycorrhizal as a potential source of AM inoculum was considered a preferential strategy for ensuring the successful re-establishment of native shrub species in semi-arid degraded soil (Caravaca *et al.*, 2003b). Bell *et al.* (2003) found that the susceptibility of *Acacia* seedlings to colonization by AM fungi appeared to be seasonal. Seasonal patterns in the formation of mycorrhiza have also been said to vary considerably from year to year (Allen *et al.*, 1981). Colonization increased with increasing daytime temperatures and day length. There is generally a good correlation between the levels of infection of the root and the mycorrhizal response. This can be affected by several factors such as, differences in plant susceptibility to infection, differences in inoculum potential, the type of inoculum can affect the speed of infection and therefore the response (Haselwandter and Bowen, 1996) and AM fungi differ markedly in their response to high soil phosphate and to such factors as soil pH (Abbott and Robson, 1985).

2.3. Association of AMF and Roles on crop growth

There is a growing body of evidence that AM can increase plant growth, especially in infertile soils, and that such growth-increases are the result of an enhanced ability of infected roots to absorb nutrients (Gerdemann, 1968). In so doing the hyphae of AM fungi have the potential to greatly increase the absorbing surface area beyond the root into the surrounding soil to improve the uptake of poorly mobile ions such as P, Zn and Cu where by their uptake depends on the root density per volume of soil. Investigators have developed improved inoculation techniques and their results tend to fit a consistent pattern. Using nonsterile soil as an inoculum, (Asai, 1943), demonstrated that mycorrhizal plants grew faster than non-mycorrhizal plants. (Peuss, 1958), using infected roots as inoculum, obtained increases growth of mycorrhizal tobacco grown in a fallow soil and in a subsoil., and Meloh (1961, 1963) showed that the growth of maize and oats could be improved by AM fungi. Gerdemann (1964) also demonstrated improved growth in maize. (Habte and Fox 1989) found a range of responses of *L. leucocephala* to inoculation from a 1.5 times to 7 times increase in shoot growth due to inoculation at 48 days, depending on the soil used. Similarly, (Purcino *et al.* 1986) obtained a doubling of growth with this species from inoculation with three AM fungi, and Cornet and Diem (1982) recorded a 1.6 fold increase with *A. raddiana* and a 6.6 times increase with *A. holosericea*. There are notable cases of growth depression apparently caused by AM fungi in “non-host” species or in host’s species when phosphate availability is high (Mosse 1973; Peng *et al.* 1993).

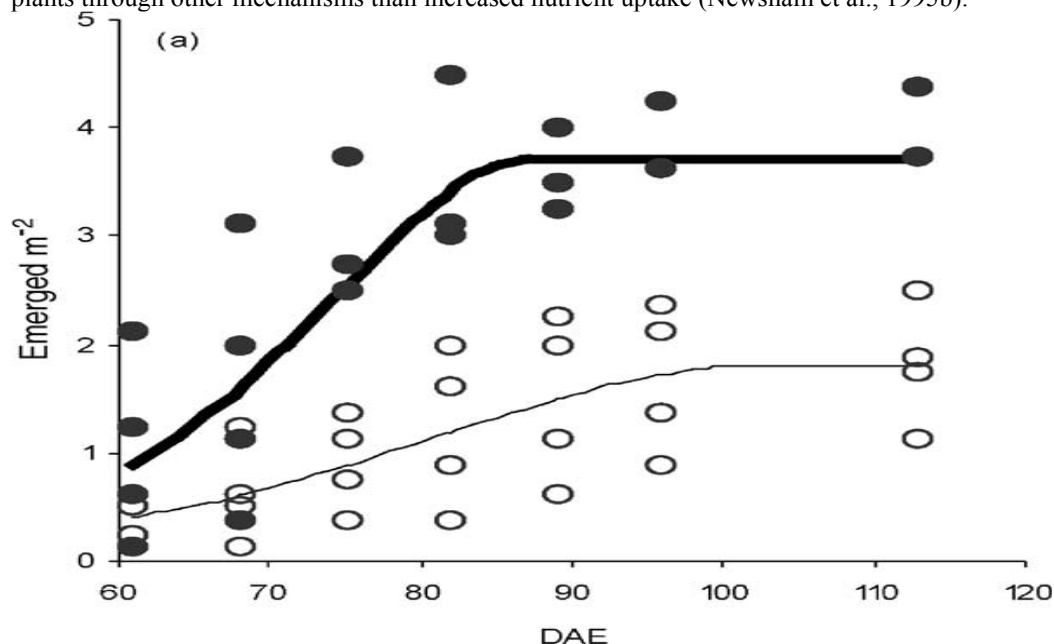
2.4. AM and Soil fertility

Three main components are involved in AM association: 1) the soil, 2) the fungus and 3) the plant. The fungal component involves the fungal structure within the cell of the root and the extraradical mycelium in the soil. The extraradical mycelium in the soil may be quite extensive under some conditions, but does not form any vegetative structures (Smith and Read, 1997). Its primary function is the absorption of resources from the soil. The increased efficiency of mycorrhizal roots versus non-mycorrhizal roots is caused by the active uptake and transport of nutrients by mycorrhiza. AM have been shown to improve productivity in soils of low fertility (Jeffries, 2002) and are particularly important for increasing the uptake of slowly diffusing ions such as PO_4^{3-} (Jacobsen *et al.*, 1992) immobile nutrients such as P, Zn and Cu (Lambert *et al.*, 1979; George *et al.*, 1994; George *et al.*, 1996; Ortas *et al.*, 1996; Liu *et al.*, 2002) and other nutrients such as Cadmium (Guo *et al.*, 1996). Under drought conditions the uptake of highly mobile nutrients such as NO_3^- can also be enhanced by mycorrhizal associations (Ázcón *et al.*, 1996; Subramanian and Charest, 1999). In legume plants the importance of AM symbiosis has been attributed to high P requirements on the nodulation and N_2 fixation process, which requires enhanced P uptake (Barea and Ázcón Aguilar, 1983). Improved P nutrition has been shown to increase in infertile and P fixing soils of the tropics (Dodd, 2000). Mycorrhizal fungi can also improve absorption of N

from NH_4^+ -N mineral fertilizers, transporting it to the host plant (Ames *et al.*, 1983; Johansen *et al.*, 1993). Its transport and absorption can also increase biomass production in soils with low potassium, Calcium and Magnesium (Liu *et al.*, 2002). Mycorrhizal fungi can potentially influence soil aggregation at different levels, namely plant communities, plant roots (individual host), and effects mediated by the fungal mycelium itself (Rillig *et al.*, 2006). Interest in AM fungi has tended to focus on their role in directly influencing the growth of the host plant. However, they also have a direct effect on soil structure, which is especially important in an agricultural context, where cultivations, trafficking and low levels of soil organic matter all tend to result in damaged soil structure (Gosling *et al.*, 2006). AM fungi increase soil aggregation by means of the physical action of the hyphae and the production of polysaccharides by the fungus or associated microflora (Tisdall and Oades, 1979). Thus they add to soil stability (Tisdall, 1994) and improve the soil structure (Forster, 1990). The extra-radical mycelium (ERM) provides a physical structure which can entangle soil particles and lead to micro-then macro-aggregate production. The recent finding that a glycoprotein called 'Glomalin' is produced by AM fungi soil-based mycelium and is a major binding agent in soils adds further weight to the importance of AM fungi in stabilizing soils and hence ecosystems (Dodd, 2000). Whether glomalin is important or not, general hyphal exudation and rapid hyphal turnover provide C to other soil microorganisms indirectly promoting aggregate stability (Dodd, 2000). The overall effect of hyphal enmeshment and C inputs can be a significant increase in soil structural stability, though the range of results, from positive, to neutral and negative suggests dependency on the host/fungal combination (Gosling *et al.*, 2006). The toxicity of metals depends on the concentrations in which they are present in the soil (Smith and Read, 1997). These metals can arise from a variety of sources in the form of acid rain, dust containing these metals, wash waters from polluted soils or from atmospheric factors produced as a result of mining, smelting, burning of fossil fuels, industrial or agricultural activities and incineration of municipal waste (Gaur and Adholeya, 2004). AM fungi alleviate plant stunting caused by toxic metals by binding to these metals in the root zone with the aid of the extra-radical mycelium and altering the plant cells ability to capture the metals (Smith and Read, 1997). The polyphosphates produced by AM fungi are proposed to be the reason behind this sequestration (Khan, 2005).

2.5. Relationship between *Striga hermonthica*, AM and sorghum

In the absence of AM fungal inoculation, there is higher numbers of *S. hermonthica* shoots emergence. Mycorrhizal sorghum plants also influences attachment and emergence of *Striga*. These results are consistent with (Lenzemo *et al.*, 2005). Field inoculation with arbuscular mycorrhizal fungi reduces *Striga hermonthica* performance on cereal crops and has the potential to contribute to integrated *Striga* management. AM fungal inoculation reduced the number and biomass of *Striga* (figure 1) (Lenzemo, 2004). However, the lower in numbers of *Striga* and biomass due to AM fungal inoculation did not show in a significant increase in grain yield of the cereals. A further confounding factor could be that not all AM fungal species are equally effective in decreasing *Striga* performance. The multi-functionality of AM symbiosis is enhancing the performance of the plants through other mechanisms than increased nutrient uptake (Newsham *et al.*, 1995b).



Source (Lenzemo *Etal*, 2004): Figure 5 emergence Pattern Of *S. hermonthica* Over Time Without AM Addition (Closed Circles) And With AM Addition (Open Circles). Observed (Points) And Those Described By

The Beta Growth Function (Curve).

Root colonization by arbuscular mycorrhizal (AM) fungi reduces stimulation of seed germination of the plant parasite *Striga hermonthica*. AM fungi have found to be a significant influence on *Striga* performance with reduced and/or delayed germination (Lendzemo, 2004), attachment (Lendzemo, 2004), and emergence (Lendzemo and Kuyper, 2001; Gworgwor and Weber, 2003). On the other hand, AM fungi had a direct positive effect on the yield of the sorghum and compensated for the damage afflicted by *Striga* (Lendzemo and Kuyper, 2001; Gworgwor and Weber, 2003). Symbiotic relationship between sorghum and AM fungi is very common (DeMars and boerner, 1995). When sorghum roots colonized by arbuscular mycorrhizal (AM) fungi the growth and development of *S. hermonthica* is influenced. Sorghum Colonization by AM fungi reduced attachment and emergence of *S. hermonthica* on sorghum (Lendzemo *et al*, 2005). The mechanisms for the lower performance of *Striga* on cereal crops upon AM fungal colonization are unknown. If the roots of cereal crops are colonized by AM fungi it reduces seed germination of *S. hermonthica* because so as to germinate *Striga* seeds in the soil require signal molecules that are exuded by the roots of their hosts, called germination stimulants. These signal molecules belong to the class of the strigolactones (Bouwmeester *et al*, 2003). This molecule has been identified as signal molecules in the interaction between plant roots and AM fungi. The double role of strigolactones (it induces for both AM and *Striga hermonthica*) suggests the earliest interaction between sorghum roots and AM fungi blocks in order not to get communication between *Striga* and sorghum consequently without getting signal it would have not been development of haustoria formation and not any attachment for growth and development with host (Besserer *et al*, 2006).

Conclusion

Agroforestry can be considered as one the best option to improve soil fertility, increase sorghum productivity and control *striga* through the enhancement of AM and AM have mechanism to control *Striga hermonthica*.

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