ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

GROWTH PERFORMANCE OF THREE INDIGENOUS AND ONE ENDEMIC TREE SPECIES OF ETHIOPIA ON A DEGRADED SITE IN CENTRAL-WEST ETHIOPIA

THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY (PLANT SCIENCES).

BY

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ABSTRACT

comparative studies on growth performance of three indigenous and one endemic tree species of Ethiopia, *viz. Cordia africana* Lam., *Croton macrostachyus (*Hochst Ex Del.), *Podocarpus falcatus (*Thunb.) Mirb. and *Millettia ferruginea* (Hochst.) Baker were conducted over a period of 8 months. The study was carried out within the landholdings of the Center for Indigenous Trees Propagation and Biodiversity Development at Tulu-Korma, about 48 km west of Addis Ababa. Tree seedlings of 88 *C. africana*, 348 *C. macrostachyus*, 256 *P. falcatus* and 303 *M. ferruginea* were planted on an area of 7,682 square meters five months before the start of this study. Each seedling was assigned a random numerical code for further follow-up studies. Watering, mulching, adding manure, and prevention measures from herbivore damage and weeding were handled by workers of the Center. Data on height and survival percentage were collected every 45 days (in 6-rounds, including data collected at time 0). Root collar diameter measurements of each coded tree were taken along with the last height measurements. Analyses of variance and Tukey's HSD tests were employed to assess the results at p=0.05. Data taken on young trees height were also used for plotting the relative growth rate for height measurements following previously adopted procedures. The analyses showed significant differences in growth changes of the tree species studied. Overall relative growth rate in height (RGRH) of M. *ferruginea* was found to be the highest, attaining a value of 0.0045. *C. macrostachyus* and *C. africana* stood second and third, with RGRH values of 0.0036 and 0.0035, respectively. There was no significant difference between the relative growth rates of *C. africana* and *C. macrostachyus*. *P. falcatus* had the lowest relative growth rate value of, 0.0028. Of the four indigenous tree species, *M. ferruginea* attained the maximum overall change in mean height of 35.3 cm. Its root collar diameter value ranked second (1.44 cm) next to *C. africana (*2.23 cm). The survival percentage was very high in all the four species, ranging between 98.86 and 100 %. Comparison of the major soil properties of the study site indicated that the area is well below the average values, with total nitrogen of 0.1% compared to the standard average value of 0.2-0.5%; organic carbon of 1.2%, compared to the standard average value of 4-10%; and available phosphorus of 2.3 ppm, compared to the standard average value of 14-19 ppm. The only soil parameter that fell within the normal range was pH (6.0). This work concludes that, despite the poor nutrient status of the site, growth performance and survival percentage of the four indigenous tree species were reasonably good, indicating the potential of indigenous trees to grow on degraded sites provided that intensive management, along with provision of water during the hot, dry season are maintained.

Key words: Tulu-Korma, survival percentage, root collar diameter, growth performance, degraded site

1. BACKGROUND

1.1. Deforestation

Natural forests of Ethiopia have been declining rapidly due to their conversion into arable lands and continued unwise utilization. These conditions are triggered mainly by rapid population growth, but also due to ignorance about propagation and field establishment of indigenous trees. The high rate of deforestation has had serious consequences on the ecosystem. (EFAP, 1994; Legesse Negash, 1995; Feyera Senbeta *et al.*, 2002). Centuries, (and even decades) ago, large numbers of indigenous tree species such as *Podocarpus falcutus* (Thunb.) Mirb., *Juniperus procera* Endl., *Cordia africana* Lam., *Millettia ferruginea* (Hochst.) Baker, *Prunus africana* (Hook. f.) Kalkm. and *Croton macrostachyus* (Del.) used to thrive within the natural forests of Ethiopia (Legesse Negash, 2002). Because Better quality timber has been produced from native trees, unwise exploitation of Ethiopia's forests was so rampant that there are few commercially exploitable forests in the country (Mesfin Tadesse, 1992).

In addition to deforestation, indigenous species are also affected by the introduction of exotic species. For instance, Thomas and Balakirshnan (1999) reported that the introduction of *Acacia auriculiforms* A. Cunn. Ex. Benth. in Kerala has affected several native species. Similar effects of exotic species have been also observed in Ethiopia (Legesse Negash, 1995, 2002). As reported by Pohjonen and Pukkala (1990) Eucalyptus trees disturb the water and nutrient balance of the soil and accelerate erosion by preventing the growth of ground vegetation.

In Ethiopia, the disappearance of forests has been most drastic in the past 100 years. In the beginning of 1900, it was estimated that about 35 % of Ethiopia's land mass, which is about 110 million hectare, was covered with high forests. By the early 1950s, the cover of high forests was reduced to 16% of the total land area. It was reported that the forest cover was 3.6 % in the early 1980s and about 2.7 % by 1989 (EFAP, 1994). The annual loss of natural forest cover has been estimated to be 150,000 to 200,000 ha. If this rate of deforestation continues, the area covered by natural forests in 2010 may be reduced to scattered minor stands of heavily disturbed forests in remote parts of the country (EFAP, 1994).

1.2. Consequences of natural forest deforestation

1.2.1. Biodiversity loss

Ethiopia is one of the most important centers of biodiversity (Vavilove, 1997), and is placed in the fifth largest flora in tropical Africa (Eshetu Yirdaw, 2001, 2002). However, these large biodiversity resources are under continuous and severe threats of destruction. It is well-known that, massive habitat loss or habitat degradation is accompanied by large erosion of genetic resources (Legesse Negash, 1995; Mulugeta Lemenih and Demel Tektay, 2004). This is because, large numbers of terrestrial organisms are found in the natural forests (Taye Bekele *et al.*, 1999). For instance, 129 endemic plant species of Ethiopia and Eritrea were threatened due to forest destruction (Ensermu Kelbessa *et al.*, 1992). In this same paper, the authors remarked that threatened endemic species require special attention because they are the only habitats in which they are found. If their habitats are destroyed, these plants are lost forever and with them go a wealth of indigenous flora and fauna which would be very difficult to replace. Similarly, Legesse Negash (2002) re-iterated that forests determine the basic fabric of life on earth. Furthermore, Taye Bekele *et al.* (1999) noted that, unless immediate rescue measures are taken, there is no guarantee that genetic resource can be transmitted to the subsequent generations.

1.2.2. Land degradation

Land degradation due to soil erosion and loss of soil fertility is one of the most visible phenomena on agricultural or deforested sites of Ethiopia. Soils of Ethiopia like other tropical countries are naturally poor in nitrogen and phosphorus, but human induced losses of soil nutrients are significant threats to the livelihoods of the people (Mulugeta Lemenih and Demel Teketay, 2004). It is well-known that degraded land is characterized by: loss of top soil and anchorage for plant roots, loss of soil nutrients, breaking of critical nutrient cycles and reduced water holding capacity of the soil (Shibru Tedela, 1994; Mulugeta Lemenih and Demel Teketay, 2004).

Accelerated soil erosion is different from the natural soil erosion process. The problems of accelerated soil erosion are mainly induced by changes in natural vegetation cover through human actions (Assefa Kuru, 1990). Through the slow process of weathering and decomposition of rocks, it takes nature nearly one hundred years to form one centimeter of soil layer; but it takes only a split second to wash it off with a storm given that the vegetative cover that protects the soil is not there (Assefa Kuru, 1990).

1.2.3. Other consequences

Water resources in Ethiopia are seriously affected by deforestation. Deforestation increases surface run-off and reduces the amount of rainfall that infiltrates the soil and percolates into the ground water aquifers. This reduced level of water infiltration and storage affects the availability of water for use by humans and other forms of life, including livestock, throughout the year (EFAP, 1994). In some cities of Ethiopia (for example, Harar, Gonder) it has increasingly become very difficult to supply the growing inhabitants with sufficient amount of clean water (Legesse Negash, 1995, 2002). This is mainly due to the absence of proper indigenous shrubs and tree species, which should maintain the watersheds of the areas surrounding these two historical cities. Increased surface run-off also results in flooding. Increased surface run-off accelerates soil erosion, which in turn reduces the life of dams such as Koka, Melka-Wakena, and Fincha due to siltation (EFAP, 1994; Legesse Negash, 2002). It must be noted that these dams are Ethiopia's lifelines as they produce electric power vital for the country's socioeconomic development.

Deforestation also results in climatic change. Reduction of trees reduces the amount of moisture in the atmosphere. Less atmospheric moisture means less or no rain, thus resulting in drought or desertification. In addition to this, global warming is also partly the result of deforestation. All these problems (deforestation, accelerated soil erosion, land degradation, etc,) are clearly associated with land resources mismanagement (Assefa Kuru, 1990).

1.3. Restoration of degraded lands

The planting and establishment of trees on degraded land should be the first important step in soil rehabilitation and land reclamation (Evans, 1992). It has been recommended that urgent actions be taken for propagating, cultivating and domesticating indigenous trees (Legesse Negash, 1995, 2002). Legesse Negash (personal communication) emphasized that indigenous forests are wombs for an array of above and below ground organisms, and thus there is urgent need to reverse the loss and degradation of indigenous trees, shrubs and herbs by restoring degraded landscapes with native forests. Eshetu Yirdaw (2001) remarked that forest plantations in Ethiopia, apart from provision of economically and socially valued forest products and services, could facilitate the restoration of floral and faunal diversity and eventually also the productivity of degraded lands.

In selecting species for reforestation, it is often best to choose the ones that are already growing in the area, since these are adapted to the environment and are thus able to regenerate naturally. If the choice lies between two species of comparable growth and quality, one of which is native and the other exotic, the native species is to be preferred (Evans, 1992).

In this regard it was reported that indigenous tree species of Ethiopia such as *Acacia abyssinica*, *Croton macrostachyus*, *Cordia africana* and *Millettia ferruginea* have fast growth performance, are culturally accepted and widely used and are adapted to local conditions (EFAP, 1994; Legesse Negash, 1995; Tadesse Hailu *et al.* 2000).

Natural forest stands and hence indigenous tree species have several important biological attributes of which the following are the main ones:

- Natural forest stands near a restoration site can provide baseline data that can be utilized in the evaluation of the extent and rate of plant species recruitment and establishment in plantations (Eshetu Yirdaw, 2001). The presence of natural stands of indigenous species in a given area can thus give a clue to undertake possible plantation activities (Evans, 1992).
- Indigenous trees are adapted to the environment and are already integral part of an ecological niche. This state of condition may make them less susceptible to serious damage from diseases and pests since predators, viruses, climatic factors are already present there (Khan, 1987; Legesse Negash, 1995, 2000).
- Indigenous species are ecologically more valuable than exotics for the conservation of native flora and fauna as well as for the conservation of water (Evans, 1992; Legesse Negash, 2007).

- The timber of indigenous species is likely to be known to local wood-using industries; it may also be preferred as a firewood source. For example, *Acacia* and *Erythrina* in the Sahel region are preferred to the introduced eucalyptus (Evans, 1992).

For these and other reasons, some major plantation programs are using native/indigenous species. For example, the indigenous *Pinus mekusii* in Indonesia and *Eucalyptus deglupta* in Philippines are grown using the same principle in their respective programs. Other few trials have been also laid down to extend further the use of indigenous species; for instance, *Cordia africana, Hagenia abyssinica* and *Podocarpus falcatus* are planted in the moist south–west part of Ethiopia (Evans, 1992). Unfortunately, in Ethiopia, reforestation programs make more use of exotic than indigenous species (Ensermu Kelbessa, *et al.*, 1992).

Azene Bekele *et al.* (1993) noted the strong promotion of exotic species without any attention being given to the rich indigenous flora of Ethiopia for reforestation purposes in the extension programs.

The overall purpose of this study is to compare growth of three indigenous and one endemic trees of Ethiopia, *viz. Cordia africana*, *Croton macrostachyus Podocarpus falcatus* and *Millettia ferruginea*. The study also aims at assessing the establishment potential of the species on a degraded site dominated by nutrient depleted black cotton soil. To date, no published growth data are available on these tree species, thus making them vulnerable to such denigrating phrases as “difficult to establish” and “slow growing”. Knowledge on the establishment potential and comparative growth of the species has its own contribution for conservation purposes (Van clay, 1994).

The study attempts to answer the following two questions:

1. How do the above-mentioned tree species differ in their respective growth rates?
2. What will be the percentage survival of the four indigenous trees under study over a period of a year?

1.4. Objectives

General objective

- ❖ To study comparative growth response and regeneration potential of four indigenous trees of Ethiopia on a degraded site.

Specific objectives

- ❖ To assess growth potential of indigenous trees used in the study on a degraded site;
- ❖ To analyze the comparative growth of the four indigenous trees of Ethiopia ;
- ❖ To recommend useful regeneration techniques that may be used by the rural community.

2. LITERATURE REVIEW

2.1. Overview of the selected species

2.1.1. *Millettia ferruginea* (Hochst.) Baker

Millettia ferruginea (Hochst.) Baker belongs to the family Fabacae (Leguminosae) (Thulin, 1989). It is an endemic, N_2-fixing tree species with multiple uses (Legesse Negash, 1995). The tree commonly occurs between 1100– 2500 m above sea level and is characterized as a component of upland forest (Thulin, 1989). It can grow into a big tree, up to 25 m. high. Its leaves are compound, each consisting of up to 27 leaflets. The flowers are violet and eventually result in fairly big, flat pods, with large, red and rounded seeds. The seeds are dispersed through self-dispersal mechanisms (Legesse Negash, 1995).

M. ferruginea is one of the most valuable multipurpose tree species of Ethiopia (Legesse Negash, 1995; Tadesse Hailu, 1997; Tadesse Hailu *et al.*, 2000; Legesse Negash, 2002). It is used to improve soil physical and chemical properties in agricultural activities, as fodder for ruminants, as a shade tree, building materials, and used as medicine (Legesse Negash, 1995, Tadesse Hailu *et al.*, 2000, Legesse Negash, 2002).

Millettia. ferruginea has the ability to re-orient its leaves and leaflets during mid-day, so as to avoid direct solar radiation (Jiregna Gindaba *et al.*, 2004). These authors have recommended that, the tree is a good candidate for drier areas as it has the advantage of higher photosynthetic rate and less water loss under severe moisture stress conditions. This physiological property, along with its capacity for fixing molecular nitrogen, makes the tree extremely useful for restoring degraded sites.

2.1.2. *Cordia africana* Lam. (synonym: *Cordia abyssinica* R. Br.)

Cordia africana belongs to the family Boraginaceae. It occurs in primary or secondary forests or in woodland at altitudes ranging from 1200-2200 m above sea level (Legesse Negash, 1995). The tree in the forest attains a height of up to 30 m, but is much smaller with curved, branched and crooked bole when growing in the open. The bark is usually pale-brown in color, rough and fibrous (Breitenbach, 1963). The leaves are alternate, large and broadly oval, in the more mature specimens becoming almost rounded. The flowers are very decorative, sessile, with white and funnel-shaped corolla. They are attractive to honey bees, and pollination is mainly effected by these insects (Legesse Negash, 1995).

Cordia africana prefers regions with relatively high rainfall and sufficiently warm climate. It can also grow under drier climatic conditions, by minimizing its water consumption through shading its leaves or by closing its stomata (Legesse Negash, 1992, 1995; Jiregna Gindaba *et al.,* 2004).

C. africana is a very fast growing tree (attaining a height of 6 - 8 m within 7 years) (Breitenbach, 1963; Mebrate Mihretu, 1999; Jiregna Gindaba *et al,* 2004). *C. africana* is easily raised from seeds in the nursery. Plantation should be laid out very dense in order to stimulate fast growth and obtain straight stems (Azene Bekele *et al.,* 1993). It is also a multipurpose tree grown in different localities for timber, soil and water conservation, and as a shade tree (Legesse Negash, 1995;

Abebe Yadessa *et al.,* 2001). Wood of *C. africana* is easily curved out to make chairs, beds, tables, doors and windows and it can be used for internal constructions. Thus the demand for wood of *C. africana* by users of its timber and timber products is enormous. However, supply is not keeping pace with the demand. Because this high demand has caused a rapid depletion of the species, the tree is now proclaimed as one of the most endangered tree species of Ethiopia (Taye Bekele *et al.,* 1999; Mebrate Mihretu, 1999; Abebe Yadessa and Dirba Bekere, 2002).

2.1.3. *Podocarpus falcatus* (Thunb.) Mirb. (synonym: *Podocarpus gracilior* Pilg.)

Podocarpus falcatus is the only representative of the family Podocarpaceae found in Ethiopia. It is a valuable indigenous tree of Ethiopia. Commercially, it is known as podo or East African yellowwood (Breitenbach, 1963; Legesse Negash, 1995; Kassa Simegn and Legesse Negash, 1996; Legesse Negash, 2002). *P. falcatus* occurs in the undifferentiated Afromontane forests, 1500- 2,800 m above sea level. It is a dominant species in the “Podo forest” and co-dominant in the “*Juniperous–Podocarpus”* forest. It is often persisting in relic forests or farm lands in areas with sufficient rainfall (Friis, 1992).

Podocarpus falcatus is very attractive, evergreen, with dense canopy and droopy branches. Moreover, the combination of dark-green mature foliage with light-green tips of the new growth gives the tree a distinctive appearance. *P. falcatus* has several ecological advantages, including provision of shade and nourishment for birds and small mammals. It also protects the soil from heavy erosion caused by stormy rainfall (Legesse Negash, 1995).

Podo is classified as a "high class soft wood", thus encouraging its selective removal from the forest. In the middle of the past century, podo was the number one commercially exploited timber species in Ethiopia, accounting for 60% of the production (Russ, 1944). Now it is estimated that only less than one percent of the original podo has survived (Legesse Negash, 1995; Kassa Semagn and Legesse Negash, 1996). Overexploitation of the seed bearing female or male trees of *P. falcatus* can reduce their genetic diversity, as well as abundance, thus resulting in local extinction.

According to Legesse Negash (1995, 2002, 2003) *P. falcatus* in Ethiopia is not only degrading but is also seriously threatened. In the same publications the author indicated that the threats are associated with the declining fertility of the remaining stands, rapid individual tree degradation (e.g. through lopping, debranching during fruit collection, debarking, as well as girdling the stems with an implicit killing of the trees). The percentage of germination of *P. falcatus* was very low (between 0 and 20) and took up to one year for the seeds to germinate on seed beds (Legesse Negash, 1995). Additionally, it was not easy to establish nursery-raised seedlings in the open field since they suffered from photoinhibition. Consequently, *P. falcatus* has previously not been easily reproduced due to lack of knowledge on its germination physiology and the ecological requirement of its seedling (Legesse Negash, 1992, 1995). Legesse

Negash (1992) recognized problem of dioecy in podo seed fertility and pioneered the development of rapid *in vitro* germination procedure. This method shortened germination time by six fold, and is now routinely used (in the Department of Biology, Faculty of Science), not only for the speedy and efficient *P. falcatus* seed germination but also for faster seedling production.

***2.1.4. Croton macrostachyus* (Hochst. Ex Del)**

Croton macrostachyus is a member of the family Euphorbiacae. The leaves are simple and broadly ovate. Its flowers are yellow-white, normally dioecious or at least on a separate shoot (Breitenbach, 1963; Friis, 1992). *Croton* is naturally regenerated from seeds and from stump sprouts. (Azene Bekele *et al.,* 1993).

It is found in a wide range of ecological distributions. In Ethiopia, it is widely distributed in the north-western highlands and in the south-eastern highlands, as far east as Harar, with an altitude ranging from 1300-2500 m above sea level. It is mostly found in the secondary formation, in secondary montane evergreen bushlands, and in moist woodland. It is often known for invading abandoned cultivations (Friis, 1992). In open areas, it is a small tree or shrub but, in a closed forest becomes a tree with a height of 25 meter or more. Cut stems of *C. macrostachyus* often give rise to large numbers of coppices. *C. macrostachyus* is not suitable for firewood owing to its bad smell and smoke when burned. Its bark is grey, soft, and liable to fungus and algae attacks.

C. macrostachyus is a valuable indigenous tree of Ethiopia. It has significant contribution in traditional agroforestry system in improving physical and chemical properties of soil and crop yield (Jiregna Gindaba, 1997; Yeshanew Ashagrie *et al.,* 1998; Dechasa Jiru, 1999). The bark and buds have several traditional medicinal uses. The sap is used as a common curative traditional medicine for fungal skin diseases (Dechasa Jiru, 1999).

C. macrostachyus has repellant chemical consistituents and hence is not attacked by insects. Additionally, it is unpalatable and is therefore not browsed by domestic or wild animals, thus allowing it to grow successfully (Dechassa Jiru, 1999). Unpalatability is an important feature especially in the Ethiopian highlands, where grazing by the largest number of live stocks in Africa is extremely serious (Pohjonen and Pukkala, 1990). Computed data from "Woody Biomass Inventory and Strategic Planning Project" indicated that *C. macrostachyus* is the first abundant indigenous tree species of Ethiopia with the total number of 54.1 million trees (Taye Bekele *et al.,* 1999).

2.2. Importance of tree seedlings care and management

After seedlings are transplanted, there should be proper care and management to ensure good survival and rapid early growth (Evans, 1972, 1992). The care/management to be undertaken may include the following:

2.2.1. Soil survey and testing

Evans (1992) reiterated that a soil should fulfill three essential requirements for plant growth: supply of moisture, nutrients and provision of mechanical support. The objectives of soil survey are essentially to assess these three functions and general features affecting its management. Information gained from soil testing is used in many ways. It could be helpful to build and/or maintain the fertility status of a given field; and evaluate the fertility status of soils on a country, soil area, or statewide basis by the use of soil-test summaries (Tisdale *et al.,* 1985).

2.2.2. Maintaining soil fertility

Before the advent of commercial fertilizers, the principal method of supplying essential nutrients to the soil was by incorporating animal manures (Tisdale *et al.,* 1985). Animal dung has to be returned to the land to maintain soil fertility. However, as the scarcity of fuel wood has grown, these organic matters have increasingly been used to meet household energy requirements (Anonymous, 1994). For every tone of animal dung not returned to the soil to improve soil fertility, there is a loss of some 50 kg of food grain (Evans, 1992). Using animal dung to maintain soil fertility is cheaper in capital cost when compared with chemical fertilizer (Tadesse Woldemariam, 2004).

2.2.3. Mulching

Any material used at the surface of a soil to assist in soil productivity may be designated as mulch. Mulches comprise plant material and residues, litter and other products (Ong, 1996). The purpose of mulching is many and varied. Direct evaporation from the soil surface could be reduced by the mulch. It also reduces wind speed and radiation at the soil surface. Thus, mulching is regularly utilized to conserve moisture, improve microclimate and reducing soil erosion. Mulching, through increased activities of soil fauna, improves soil structure and fertility (Khun, 1987; Wallace, 1996). Mulching influences organic matter content, availability of soil nutrient and soil compaction, which are helpful for better plant growth (Ranganathan and Wit, 1996).

2.2.4. Watering

Severe water stress is the dominant factor that limits the establishment of seedlings in the field in Ethiopia (Jiregna Gindaba *et al.,* 2004). After low soil fertility, water availability is the second most serious limiting biological constraint for agricultural production in Ethiopia. About 60% of Ethiopia's agricultural lands frequently experience serious drought stress (Takele Gebre, 2004). Water is required by plants for the manufacture of carbohydrates, as a vehicle for the translocation of food and minerals. Internal moisture stress causes reduction both in cell division and cell elongation, thus affecting tissue and organ growth (Tisdale *et al.,* 1985). Exposure of plants to drought stress affects not only growth but also lead to the disruption of metabolic processes. Depending on the severity of the stress, drought reduces the ability of the plant to survive and reproduce (Fitter and Hay, 1987). Watering therefore, ensures better survival and growth of seedlings.

Soil moisture exerts a powerful impact on seedling establishment, given that this stage is highly vulnerable to drought stress (Evans, 1972). Summer droughts could affect both current and future seedling performance. Irrigation during the first summer often has increased seedling survival (Castro *et al.,* 2005). A study by Castro *et al.* (2005), on the effect of alleviation of summer drought on *Pinus sylvestris* revealed the benefits of water supplementation during the first growing season. Some of the benefits were:

- Irrigation increased seedling survival during the first drought summer.
- Irrigation increased available photosynthetic tissue (longer shoots and more leaves), as well as shoot and root biomass.
- The positive effects of irrigation persisted during the second growing season (even in the absence of irrigation during the drought summer).
- Drought alleviation with water supplementation has a clear-cut effect: boosting survival after the first growing season.

2.2.5. Hoeing

Weeds can damage young trees in many ways. Weeds directly compete for light, moisture, and nutrients. Some can even smother, eventually killing plants by their cumulative weight, shading and growth habit-twining and twisting. Thus, removal of weeds is essential for good early growth of seedlings (Evans, 1992), and this is achieved by frequent hoeing of young tree seedlings.

Soil aeration is essential for meeting the respiratory requirements of both roots and soil micro organisms. The transfer of gases between soil and the atmosphere occurs mainly in air-filled pores since gas diffusion in air is about 10^4 times more rapid than in water (Marschner, 1995). Poor soil aeration and a decrease in O_2 are correlated with a simultaneous increase in CO_2. Lack of aeration in the subsoil restricts root growth in soils with a high water table (Marschner, 1995).

2.2.6. Seedling protections

Almost all seedlings are vulnerable to browsing unless they are protected. Animals, especially the domestic ones, seriously damage young trees and they have to be excluded from stands until trees are 3-4 m tall. The damage is not only on the leading shoots, but cattle will often lie against a tree, which may bring physical damage on the whole plant body. Therefore, protection against animals where browsing pressure is high must be enforced, though it is rarely straight forward. Erection of fences or walls or use of shepherds are expensive, but may be the only solution available (Evans, 1992).

2.3. Seedling growth

2.3.1. Growth and measurement techniques

Growth in plants is defined as an irreversible increase in volume. The largest component of plant growth is cell expansion driven by turgor pressure. During this process, cells increase in volume and become highly vacuolated (Taiz and Zeiger, 2002).

Growth can also be measured in terms of change in fresh weight: that is, the weight of the living tissue over a particular period of time. However, the fresh weight of plants growing in the soil fluctuates in response to changes in the water status, so the criterion may be a poor indicator of actual growth. Thus, measurements of dry weight are often more appropriate than the fresh weight (Taiz and Zeiger, 2002).

2.3.2. Destructive and non-destructive measurement techniques

Measurements of above-ground biomass could be made through two basic ways, *viz.* destructively and non-destructively. Among the various methods for evaluating forest biomass, the most widely used is complete harvest of randomly selected plots (destructive method). However, such methods are not suited to the natural environment, especially if the environment is highly degraded and also with threatened species (Montes *et al.,* 2000). In the same paper, the author commented that, destructive method is expensive in terms of time and expended for collecting the data when compared with the non-destructive method.

The other alternative way of measurement of biomass is non-destructive sampling. Total harvesting is generally impractical or inappropriate in forest studies; so allometric methods have been developed to estimate total biomass from non-destructive surrogate measurements such as diameter of the bole at breast height (dbh) or recording the height of selected plants (Vann *et al.,* 1998). Alternatively an aerial photo can be processed to give the "area" of each plant in the experiment.Taking tree shape into account permits estimation of the biomass for species with complex shapes. This method appears to be reliable to study the above-ground biomass of isolated trees as well as for tree stands in open woodlands.

The non- destructive measurement technique has the following advantages:

- It enables to study evolution of individual tree biomass and its components by taking photographs at several year intervals (Montes *et al.,* 2000).
- Without disturbing the environment, it is possible to obtain accurate biomass data in endangered ecosystems due to intense anthropogenic degradation or climatic change (Vann *et al.*, 1998, Montes *et al.,* 2000).
- It can determine the biomass and leaf area of individual tree throughout their growing cycle. Hence, it is an essential tool, to provide periodic measurements of tree productivity (Lott *et al.,* 2000).

3. MATERIALS AND METHODS

3.1. The study site

The study was conducted within the landholdings of the Center for Indigenous Trees Propagation and Biodiversity Development at Tulu-Korma (Oromia Region, West Shewa Zone, Ejere Wereda). Tulu-Korma is located at 09^0 01′ N latitude and 38^0 21′ E longitudes, geographic coordinates and is about 3 km from Addis Alem, along the highway to Ambo (Figure 1). The altitude of the study area is between 2160-2180 m a.s.l., and lies in an area of previous teff cultivation land that has been designated as 'Teff Block' (Fig. 1).

The area receives an average annual rainfall of 1100 mm in two short seasons: short rains *(Belig)* from February to May and long rains (*Meher)* from mid-June to mid –September (Hailu *et al.,* 1990). The short rains are mainly used only to break and prepare the soils for crop cultivation. The pattern of rainfall dictates the single cropping period, starting in March and ending in December. The mean maximum and minimum temperatures are 22.5 and 15^0 C, respectively (Buta, 1977).

The soil of the study site is pellic vertisols, dark in colour. Vetisols develop from igneous and metamorphic rocks. The extent and nature of shrink-swell in vertisols are function of clay. Their cohesiveness when wet causes problems of workability. Shortage of nitrogen occurs as a result of poor drainage and relatively low content of organic matter. Next to nitrogen, phosphorous is deficient in vertisols (Mesfin Abebe, 1998).

The natural forest is almost totally removed by human interference and now few scattered trees have remained. The few remnant natural tree species in the area are *Acacia abyssinica, Juniperus procera, Podocarpus falcatus, Croton. Macrostachyus, Ekibergia capensis* and *Olea europea.* Some of the shrub species are *Maytenus* spp.*, Carissa edulis, Myrsine africana*. Of the herb species *Ricinus communis, Bidens biternata* and, *Dautra* are the main ones .Grasses such as *Cynodon dactylon* and *Digitaria spp*. are inhabitants of the area. Land degradation due to soil erosion and loss of soil fertility is one of the visible phenomena on agricultural or deforested sites (Mulageta Lemenih and Demel Teketay, 2004). Similar conditions are observed in this study site.

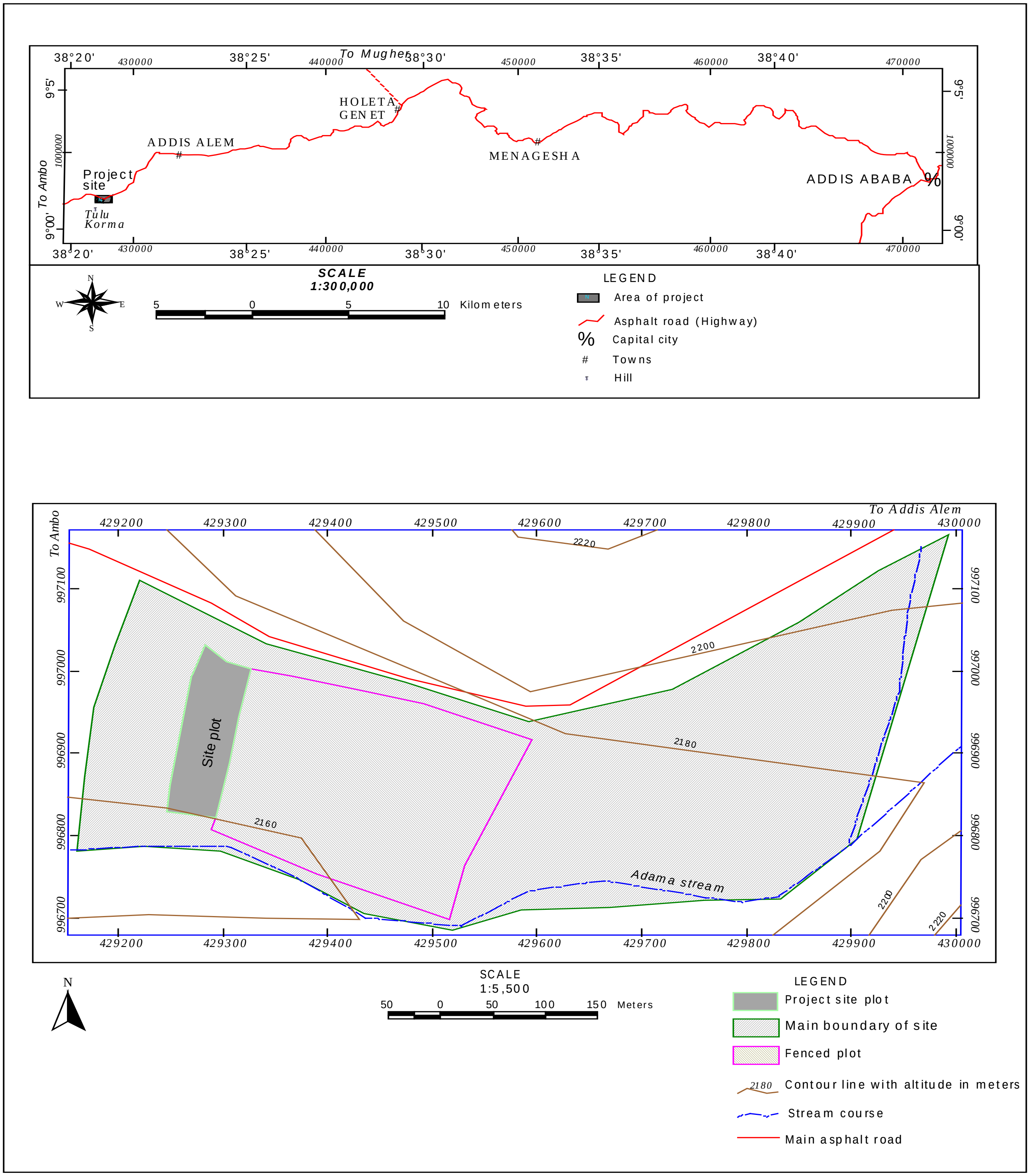

Figure 1. Location of the project area

Fig. 1. Location of the “Center for Indigenous Trees Propagation and Biodiversity Development” at Tulu-Korma. The study area is indicated on the left-hand- side as “site plot”.

3.2. Experimental design

The experimental site was 167 x 46 m in area. A total of 995 seedlings of the four indigenous tree species studied were planted five months before the start of this study (in May, 2005). The numbers of individual trees in the study site were: 256 for *P. falcatus*, 88 for *C. africana*, 303 for *M. ferruginea* and, 348 for *C. macrostachyus*. The study area was divided into eight (20 x 46 m), sub plots each consisting of the four indigenous tree species studied. To make the measurement process easier, boundaries of one meter wide were laid among the sub plots. Each seedling was given a tag with its corresponding numerical code.

Care was provided to the planted seedlings through, watering, mulching, hoeing, adding manure and protection from browsing domestic and wild animals. However, because of the large numbers of domestic and some wild animals in the area, provision of 100% protection was not possible.

3.2.1. Watering

Water was pumped from a dam using a water pump and a delivery hose of 300 m attached to the pump. The pumped water was stored in three big ditches, with a capacity of ca 300 liters each. Since the soil is pellic vertisol, sippage in to the ground had been minimal. Each seedling was watered every three days during the first three months of the dry season, namely November, December and January. This was followed by a watering regime of every seven days during the months of February, March, April and May.

3.2.2. Other activities

Hoeing the seedlings using hoes and mowing grass and weeds using sickles was also an important activity for better soil aeration and for avoiding weeds. Mulching and adding manure were also carried out for facilitating seedlings growth and for conserving soil moisture.

3.3. Data collection

3.3.1. Seedling height

Seedlings height was measured from the base to the highest point of the plant every 45 days (from Oct. 2005 to May 2006) and the average mean height for each species was recorded.

3.3.2. Root collar diameter

Root collar diameter of each seedling was taken using vernier caliper (in May, 2006), and the mean diameter for each tree species was computed.

3.3.3. Survival percentage

Number of wilted or dead seedlings from each species was counted and recorded every forty five days. Then at the end of the study period (using total number of dead seedlings) survival percentage was calculated.

Herbivore damage

Massive or partial defoliation of seedlings together with removal of meristimatic tips by cattle and wild animals was recorded until the end of the study period.

3.3.4. Soil sampling and analyses

From each of the 8 sub plots of the study area, 1 kg of composite soil sample was taken from the four corners as well as from the middle areas, of the study site from depths of 0-15 cm. The soil parameters analyzed were pH, total nitrogen, available phosphorus, bulk density, texture and organic carbon. The soil analysis work was done in the laboratories of the National Soils Research Center (Addis Ababa), and East Gojjam Zone Soils Research Center (Debre Markos) (for the analysis of nitrogen). The methods used in the analyses were as follows:

For **soil pH** measurements a 1:2.5 soil to water ratio was used (London, 1984). The suspension was stirred occasionally, and the pH was determined after 30 minutes using a pH meter, standardized by buffer solutions of pH 4 and 7.

The **soil texture** was determined by hydrometric method of mechanical analysis (London, 1984). Soil suspension was allowed to stand for 30 minutes, Then stirred for 15 minutes, and transferred to a measuring cylinder. The cylinder was filled to the mark and the first hydrometric and temperature reading were taken after 40 seconds. The second hydrometer and temperature readings were taken two hours after the first reading and the percentage of the various soil separates were determined following the standard formulae (London, 1984).

For the **bulk density** measurement of the soils, an undisturbed soil core was removed by driving a metal cylinder about 7.5 cm in diameter and 7.5 cm in height on a level and neat soil surface. The metal cylinder filled with soil was removed and dried in an oven at 105^0 C to a constant weight. The volume of the soil core was estimated from the internal radius of the metal cylinder. The mass of oven dry soil core, divided by its volume (cm^3) results in the bulk density (g/cm^3) of soil.

Total nitrogen was determined by Kjeldahl method. The organic matter of the soil sample was oxidized by treating it with concentrated sulfuric acid, where nitrogen in the nitrogenous compounds was converted into ammonium sulphate. The acid traps NH_4^+ ions in the soil, which were librated by distilling with NaOH. The librated NH_4^+ absorbed in boric acid and back titrated with standard H_2SO_4. The amount of nitrogen is estimated from the amount of NH_4^+ librated by distilling the digest with NaOH.

Organic carbon of the soil was determined by wet oxidation method of Walkley and Black. Organic carbon is oxidized by a measured amount of excess $K_2\ Cr_2\ O_7$ in the presence of H_2SO_4 in Erlenmeyer flask. The amount of O_2 consumed during the oxidation of organic carbon is calculated from the amount remaining after oxidation. This is determined by titration with 0.5 N ferrous sulphate in the presence of redox indicator diphenyl amine. The percent of carbon was calculated using the following formula (Jaiswal, 2003).

$$\%\ \text{of organic carbon in the soil} = \frac{(B-S)\times 0.003\times 100}{W}$$

Where: B = volume of Fe $(NH_4)_2$ $(SO_4)_2$ used for reducing 10 ml of 1.0 N potassium dichromate;

S = volume of Fe $(NH_4)_2$ $(SO_4)_2$ used for reducing the excess potassium dichromate in the sample;

W = weight of sample in gram.

Available phosphorus in the soil was determined by extraction according to Olsen. Phosphorus was extracted from the soil by bicarbonate solution at pH 8.5. Phosphorus in the soil extract was determined by colorimeter after developing molybdenum blue color, the intensity of which varies with the phosphorus concentration.

3.4. Statistical analysis

Data on height and root collar diameter were subjected to ANOVA to determine differences among the four species in their growth. Tukey's HSD test was employed for Multiple Comparisons when significant differences were found between the growths of the species ($p= 0.05$). Chi-square analysis was carried out to observe associations between rate of herbivore damage and type of species. The statistical software was SPSS for Windows version 11.0.

Data collected on seedlings height were also used to plot the relative growth rate (RGR). Relative growth rate for height (RGRH) was calculated by using the formula below (Evans, 1972).

$$RGR\ H\ (cm\ cm^{-1}\ d^{-1}) = \ln TSL_2 - \ln TSL_1 / t_2 - t_1$$

Where: $\ln$ = natural logarithm;

TSL_2 = total shoot length at final measurement;

TSL_1 = total shoot length at initial measurement;

$t_2 - t_1$ = days between measurements.

4. RESULTS

4.1. Comparative growth of the four tree species studied

4.1.1. Growth in height

Differences in the mean height between the initial and the last measurements (225 days) were significant for all studied species (p=0.05). The changes in height among the four species (ordered from high to low) were: (35.3 cm for *Millettia ferruginea)*, (28.6 cm for *Cordia* a*fricana)*, (17.9 cm for *Podocarpus falcatus*), and (17.6 cm for *Croton macrostachyus)* (Fig. 2).

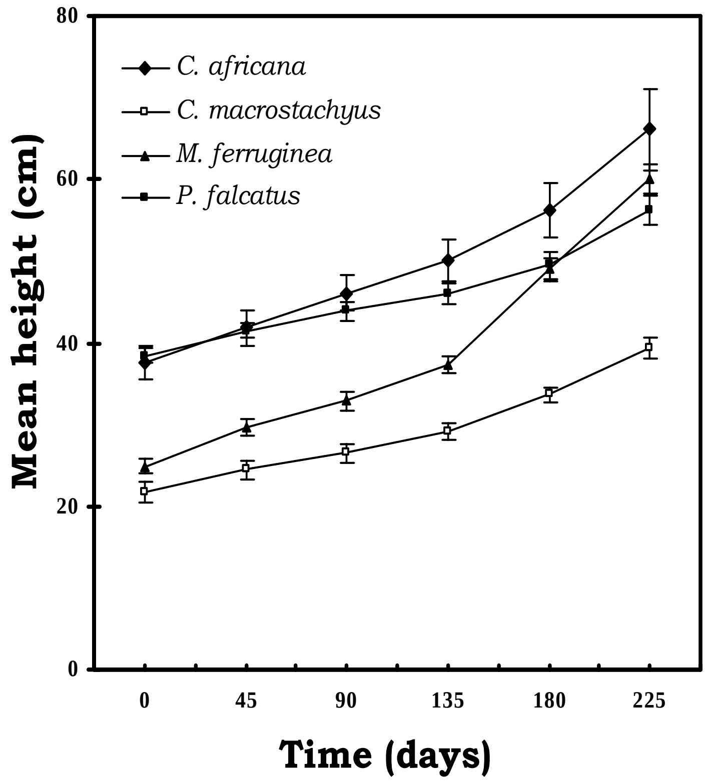

Fig. 2. Mean growth in height of the four young indigenous tree species over a period of 225 days. Height increments were recorded every 45 days. Initial measurements were conducted five months after planting the tree seedlings. Bars represent ± S.E. (N=76-324).

When seedlings mean height increments between consecutive measurements were compared, the computed values for the four tree species were significantly different from one another. These mean changes in height were also not constant for any single species throughout the study period (Fig. 3).

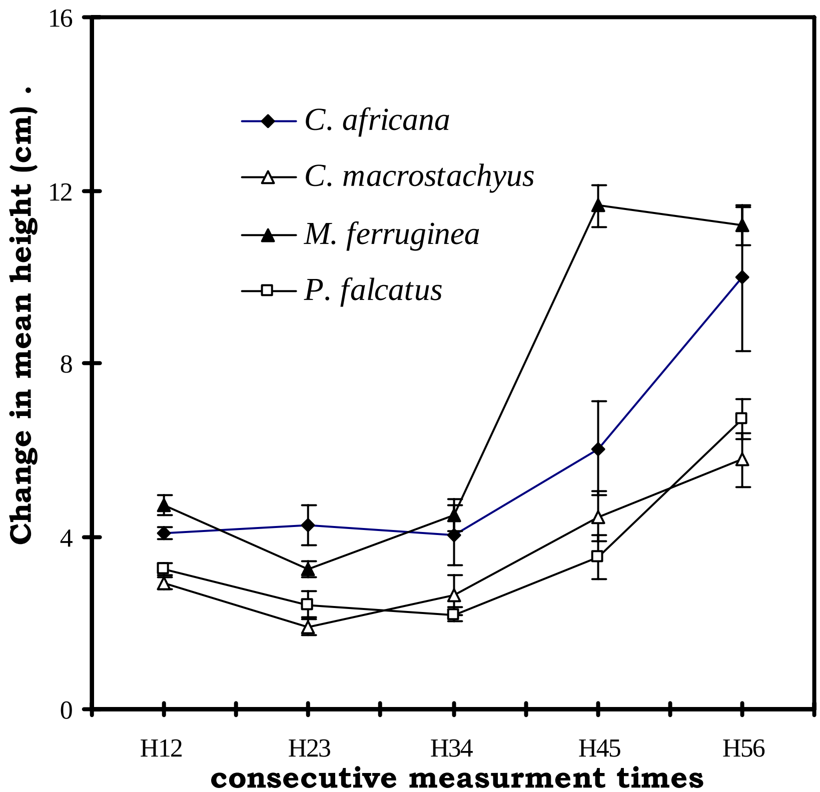

Fig. 3. Changes in mean height of the four young tree species between two consecutive measurement times ($H_{1,2}$; $H_{2,3}$; $H_{3,4}$; $H_{4,5}$; and $H_{5,6}$ refer to mean height increments between two consecutive measurement times 1& 2, 2 & 3, 3 & 4, 4 & 5, and 5 & 6, respectively. Bars indicate ± S. E. (N=76-324). Maximum change in height growth on the last measurement date was attained by C. *africana* with a mean height of 66.1 cm. The second species was M. *ferruginea* with a mean

height of 60.1 cm. The third was *P. falcatus* with a mean height of 56.2 cm followed by *C. macrostachyus* with a mean height of 39.4 cm (Fig. 4).

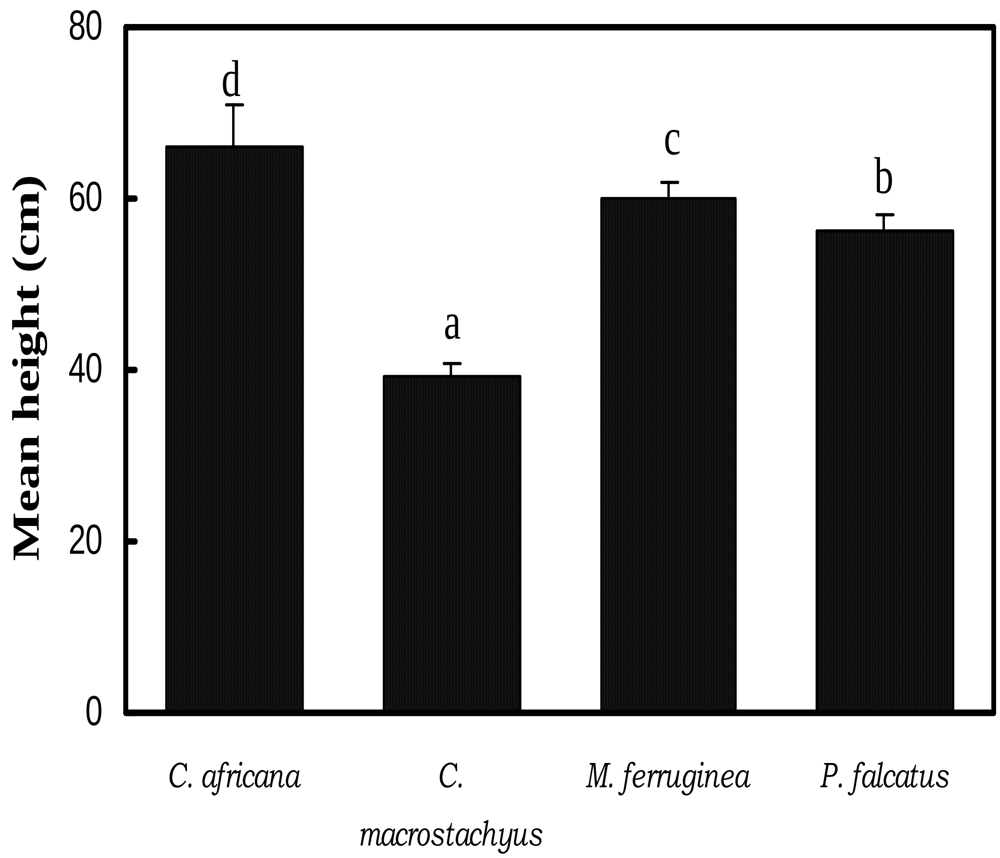

Fig. 4. Mean height of the four young tree species at last measurement. Means with different letters are significantly different from each other at p = 0.05. Bars indicate ± S.E (N=76-324)

Relative growth rate of seedlings in terms of height (RGRH)

The relative growth rates in height (RGRH) of the four young tree species were different among one another during the entire study period. The RGRH of each young tree species was also different during the dry (days 45-135) and the small rainy (days 136-225) seasons (Fig. 5).

The value of RGRH for *C. africana* declined from mid-November to January ($RGRH_1$ > $RGRH_2$). These months were cold, (during nights) and dry (during days). However, all RGRH values of *C. africana* except $RGRH_5$ were not significantly different from each other (p = 0.05). $RGRH_5$ computed for the period (April to mid-May) was the highest significant value, compared with other RGRH values of the species.

$RGRH_1$ of *C. macrostachyus* was significantly (p=0.05) higher when compared with the value of $RGRH_2$. This marked decline in RGRH was observed from mid-November to January. Thereafter, the seedlings were having more or less improved values of RGRH. A marked difference was observed between the values of $RGRH_3$ and $RGRH_4$. The difference between $RGRH_4$ and $RGRH_5$ was not statistically significant (p=0.05).

$RGRH_2$ of *M. ferruginea* from mid-November to January was significantly lower than $RGRH_1$. These months were cold (during nights), dry (during days) and windy. The tree species attained the highest significant value (p=0.05) in $RGRH_4$

(mid-February to April). From the beginning of April to mid -May, good growth rate was seen, although this was significantly ($p=0.05$) lower than $RGRH_4$. The difference between $RGRH_2$ and $RGRH_3$ is not statistically significant. All the other RGRH values of *M. ferruginea* are statistically significant ($p=0.05$).

P. falcatus, like *C. africana*, had relatively lower RGRH from mid- November to January ($RGRH_1 > RGRH_2$). These months were cold (during nights), windy and dry (during days). A markedly decreased $RGRH_3$ value was observed during January to mid-February. *P. falcatus* attained its highest and significant ($p=0.05$) values of $RGRH_5$ during the 45 days between April to mid-May.

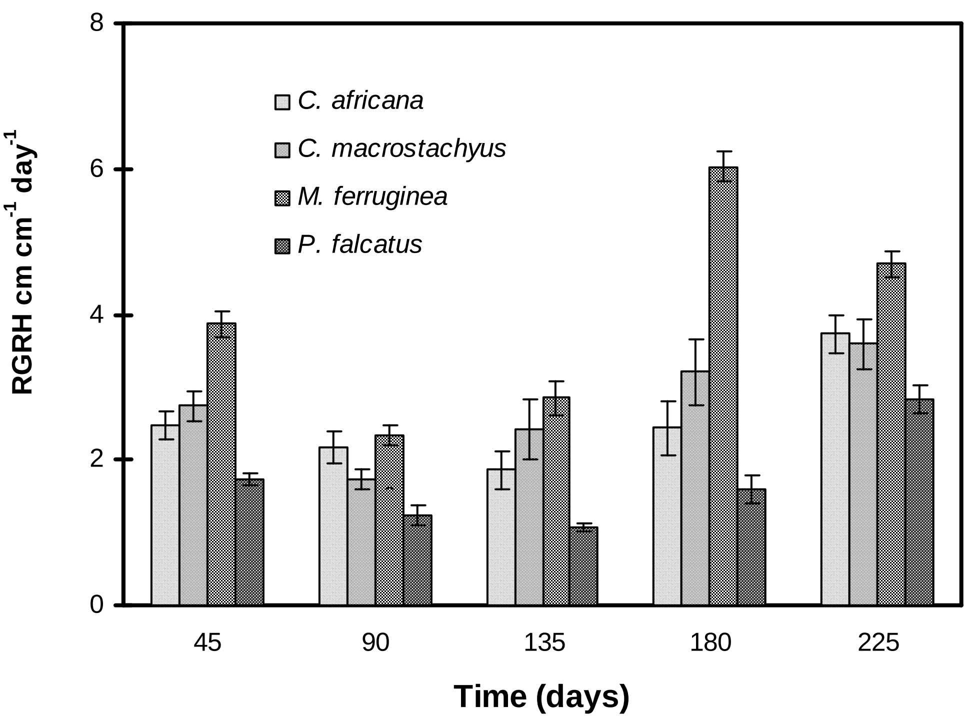

Fig. 5. Mean relative growth rate in height (RGRH) of the four young tree species at different measurement points (45 days $=RGRH_1$; 90 days $=RGRH_2$; 135 days $=RGRH_3$; 180 days $=RGRH_4$; and, 225 days $= RGRH_5$). Bars indicate ± S.E. (N=76-324).

When comparison was made among the RGRH values of the species, the mean RGRH values of *C. africana* and *C. macrostachyus* were not significantly different (p = 0.05). Compared to all the other young tree species, *P. falcatus* scored significantly (p=0.05) lower overall RGRH. In contrast, *M. ferruginea* had the highest significant (p=0.05) RGRH value (Fig. 6).

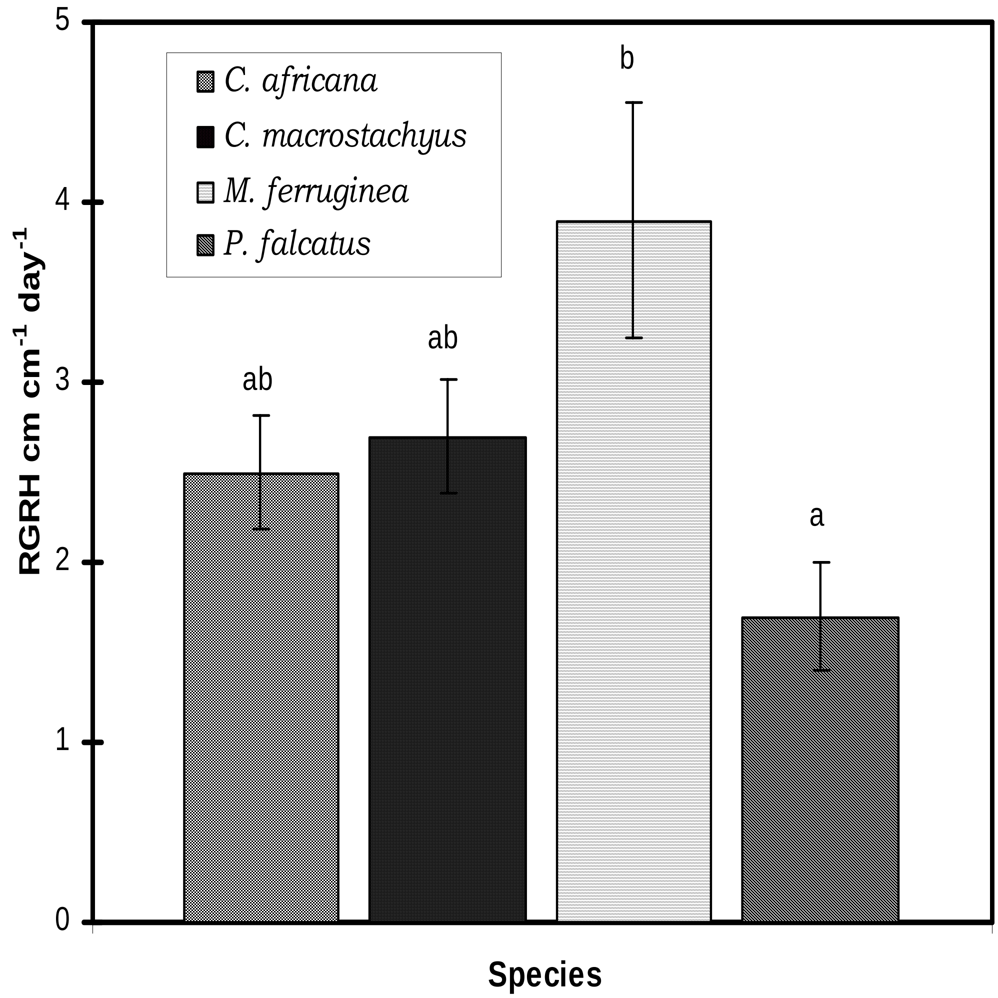

Fig. 6. Overall mean relative growth rate in height (RGRH) of the four young tree species. Bars indicate ± S.E. Means with the same letters are not significantly different from each other at p= 0.05 (N=76-324).

4.1.2. Root collar diameter (RCD)

Root collar diameter (RCD) measurements of the four young tree species were taken along with the last growth in height measurements. *C. africana* was with the highest significant (p=0.05) RCD value (2.23 cm), followed by M. *ferruginea* (1.44 cm). *P. falcatus* ranked third with a value of 0.88 cm, and the last was *C. macrostachyus* with root collar diameter of 0.87 cm. However the values of *P. falcatus* and *C. macrostachyus* were not statistically significant at p=0.05 (Fig.7).

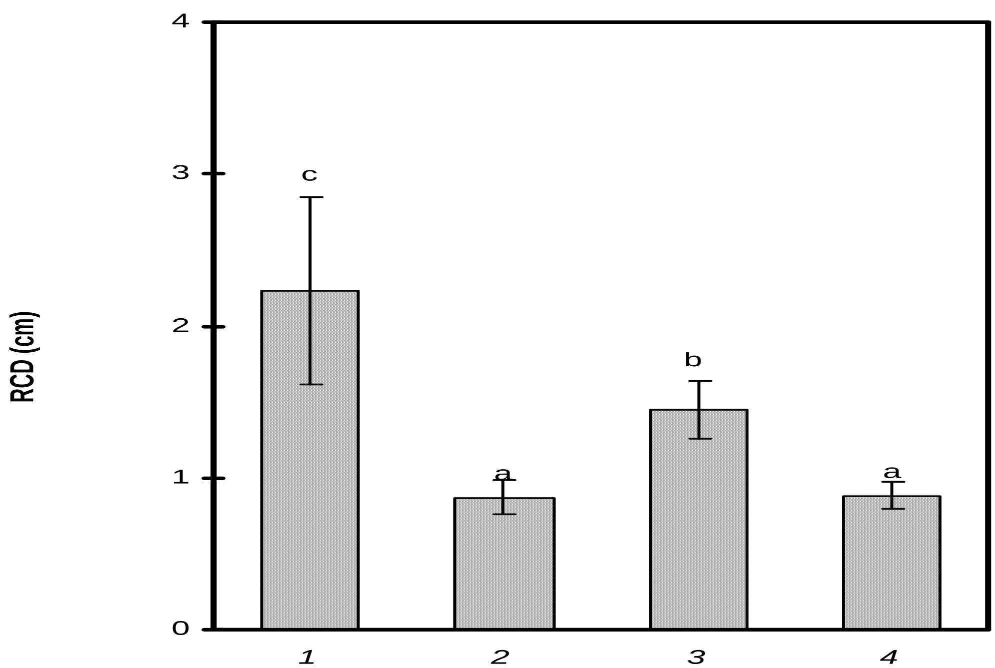

Fig. 7. Mean root collar diameter (RCD) of the four young tree species studied. Means with the same letters are not significantly different at p = 0.05. Bars indicate ± S.E. (N=76-324). (1=*C. africana;* 2= *C. macrostachyus; 3= M. ferruginea;* 4= *P. falcatus).*

4.2. Survival Percentage

The overall survival percentage during the study period was high for all the four young indigenous tree species, ranging from 98.86 to 100 %(Table 1). However, it must be noted that the concept of survival is relative since some of the young trees that have survived during the entire study year may die during the following years. It is, therefore, not wise to be euphoric about the above percentage survivals until the trees establish in the site. This process might take about 4-5 years, given for the degraded nature of the site (Table 4) where the current studies were conducted.

Table 1. Survival percentage of the four young tree species within the study period of 225 days.

Species	N (at the beginning)	Wilted/died	Survival percentage
C. africana	88	1	98.86
C. macrostachyus	348	2	99.43
M. ferruginea	303	2	99.34
P. falcatus	256	0	100

4.3. Herbivore damage

Herbivore damage by cattle and wild animals was observed in all the young tree species, except *C. africana*. Percentage of herbivory was highest in M. *ferruginea.* Damage due to herbivory is arranged in decreasing order as follows: *M. ferruginea, P. falcatus*, *C. macrostachyus* and *C. africana* (Fig. 8).

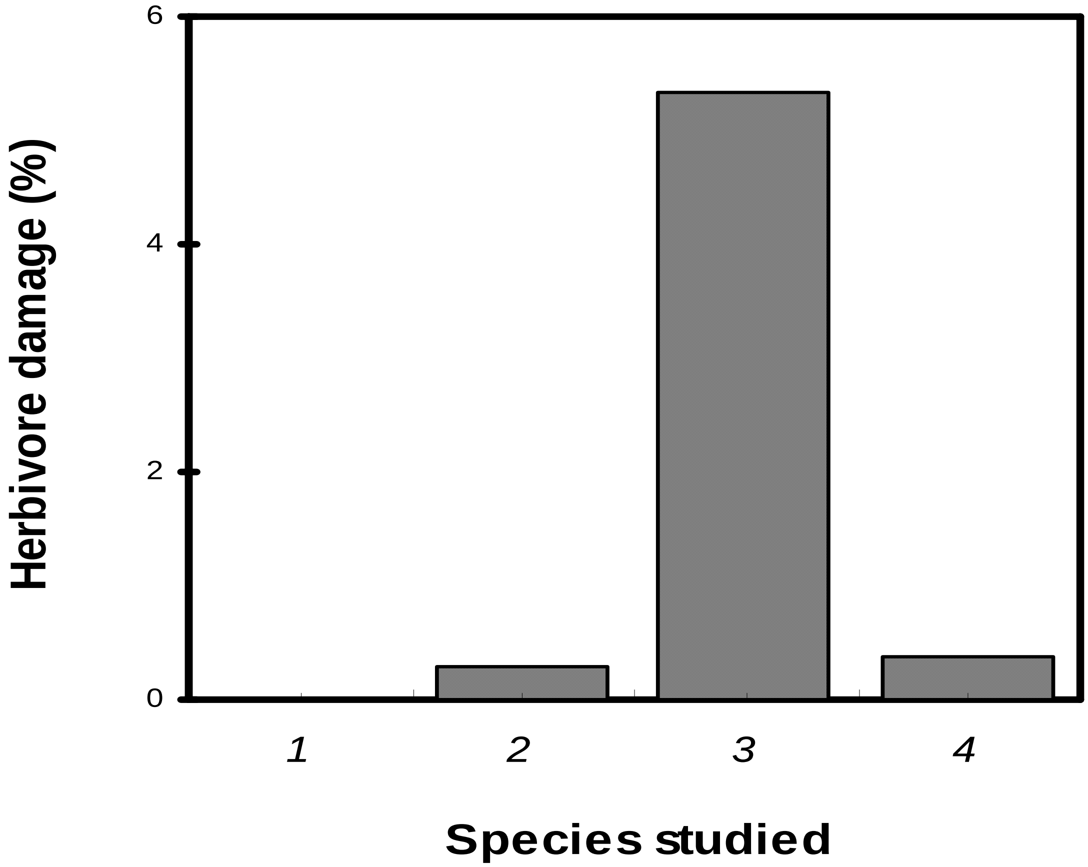

Fig. 8. Herbivore damage in the four tree species studied over a period of 225 days. (1= *C. africana;* 2=C. *macrostachyus*; 3=*M. ferruginea* and 4=*P. falcatus*).

Herbivore damage was also not similar in the different sub plots of the study site. For example, in the first three sub plots (sub plots 1, 2, and 3) the damage was high (83.3 %), and on the other hand, no herbivory was observed in sub plots 4, 5 and 7 (Table 2). It was noted that vulnerability of the plants to herbivores depended not only on their innate physical and chemical characteristics, but also accessibility of the herbivores to the young trees.

Table 2. Browsed seedlings of the four young tree species by plots and species (determined within the study period of 225 days).

Sub Plot No.	Browsed seedlings number by species				
	Cordia africana	*Croton macrostachyus*	*Millettia ferruginea*	*Podocarpus falcatus*	Total
1	0	0	2	1	3
2	0	1	8	0	9
3	0	0	3	0	3
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	2	0	2
7	0	0	0	0	0
8	0	0	1	0	1
Total	0	1	16	1	18

Out of the18 browsed young trees 16 (88.9 %) were *M. ferruginea.* The percentage of browsed *M. ferruginea* was statistically significant (p=0.05) from the other three species, and was particularly susceptible to browsing by cattle.

4. 4. Results of soil analyses

Results of soil analyses (composite samples from the study site) at a depth of 0-15 cm for pH, texture, total nitrogen, organic carbon, available phosphorus and bulk density are presented in Table 3.

Comparison of the major soil properties of the study site indicated that the area is well below the standard, total nitrogen (0.1% compared to the standard average value of 0.2-0.5%), organic carbon (1.2%, compared to the standard average value of 4-10%), and available phosphorus (2.3 ppm, compared to the standard average value of 14-19 ppm). The only soil parameter that fell within the normal range was pH (6.0) (Table 4).

Table 3. Some characteristics of the pellic vertisol in the study site at Tulu-Korma. Eight composite soil samples (from a depth of 0-15cm), each weighing 1 kg, were collected from each of the 8 sub plots of the study site.

Sub Plot #	p^H	Sand (%)	Silt (%)	Clay (%)	Class	Total N (%)	Organic Carbon (%)	AV. P (ppm)	Bulk density (g/cm3)
1	5.8	15	24	61	Clay	0.15	1.29	2.50	1.45
2	6.3	11	22	67	Clay	0.13	1.29	1.76	1.17
3	6.4	11	22	67	Clay	0.08	1.09	1.76	1.19
4	6.0	9	22	69	Clay	0.11	1.05	2.36	1.14
5	6.0	11	22	67	Clay	0.07	1.12	2.32	1.36
6	5.9	9	22	69	Clay	0.07	1.10	2.32	1.21
7	5.9	9	20	71	Clay	0.15	1.07	2.30	1.06
8	5.8	11	22	67	Clay	0.13	1.23	1.78	1.36

ppm= parts per million.

Table 4. The status of Tulu-Korma soil property as compared with established reference values.

No	Soil property	Unit	Reference1		Soil test result (Tulu Korma)
			Range	Rating	
1	pH (1:2.5)11	----	>8.5	Very high	
			7-8.5	High	
			5.5 - 7	Medium	6
			< 5.5	Low	
2	Total N	%	>0.5	High	
			0.2- 0.5	Medium	
			< 0.2	Low	0.1
3	Organic C	%	10 – 20	High	
			4-10	Medium	
			< 4	Low	1.2
4	AVP	ppm	< 5	Very low	2.3
			6-13	Low	
			14-19	Medium	
			20-28	High	
5	Bulk density	g/cm³	0.9-1.2	recently cultivated	1.2
			1.2-1.4	Non compact	
			> 1.46	compact	

1 Source for the reference value: London (1984).
11 Soil water ratio used.

5. DISCUSSIONS

The growth in height assessment of the four young indigenous tree species showed significant differences among the studied trees. *M. ferruginea* performed best with respect to changes in mean height (Figs. 2 and 3*)*. Earlier studies have also shown M*. ferruginea* as one of the fastest growing indigenous tree species of Ethiopia (EFAP, 1994; Legesse Negash, 1995; Tadesse Hailu *et al.*, 2000; Legesse Negash 2002).

The mean relative growth rate in height (RGRH) of *M. ferruginea* was the highest among the studied tree species (Fig. 5). In particular, the RGRH values, from January to April ($RGRH_3$ and $RGRH_4$l) were found to be significantly ($p=0.05$) different from all the other species. These growing seasons were warm and dry. As mentioned by Jiregna Gindaba *et al.,* (2004) *M. ferruginea* has the advantage of higher photosynthetic rate and less water loss under moisture stress conditions. This could be one of the reasons for better growth performance of *M. ferruginea* when compared with the other studied young tree species. In addition to this, Legesse Negash (2000) and Maikhure *et al.* (2000) reported that, the ability to fix atmospheric nitrogen is important to speed up growth of plants. This has clearly been the case for *M. ferruginea.*

C. africana also achieved a good performance in its height growth and in root collar diameter. *C. africana* is a very fast growing tree, attaining a height of 6-8 m within 7 years (Breitenbach, 1963). Mebrate Mihiretu and Belachew Gizachew (2004) reported that the mean height of one- year-old seedlings of *C. africana* was 1.2 -1.7 m, depending on the provenance but the soil parameters under which the trees were grown were not reported in their study. In the current study, the mean height of one- year-old *C. africana* was less than the previously reported ones. The reported early fast growth of the species was not observed at this site, and so did not agree with other findings. This should not be surprising since the soil analysis results for the major parameters showed that the site is degraded, and that the vertisol cracks during dry seasons, thus making root growth extremely difficult.

The value of RGRH of *C. africana* declined from November to January. These two months were very cold during nights, hot, dry and windy during days. Amanuel Mehari (2005) reported the sensitivity of *C. africana* to frost.

At the beginning of the study, there were 88 seedlings of *C. africana.* Later on, tips of 11 seedlings dried and were discarded from the data. However, within the time of two to three months, the seedlings with dried tips started to grow again, but produced double leaders, thus resulting in branched features, such seedlings may produce crooked stems later in their life cycle. The crooked stem of *C. africana* was reported by several workers, (Breitinbach, 1963; Mebrate Mihretu, 1999; Mebrate Mihiretu and Belachew Gizachew, 2004; Amanuel Mehari, 2005). In this study a seedling with a single leader shoot was observed to be taller than a seedling with double leaders. Double leaders influence the rate of seedlings height growth (Cadenasso and Pickett, 2000).

Different mechanisms are proposed to improve stem quality and enhance growth of *C. africana* trees. It has been suggested that the establishment of closely spaced plantations followed by thinning would improve stem form provided that, water and nutrient requirements of the planted trees are satisfied (Mebrate Mihiretu and Belachew Gizachew, 2004, Amanuel Mehari, 2005).

There was no significant difference between the relative growth rate of *C. africana* and *C. macrostachyus*. Thus, *C. macrostachyus* was also with a good growth performance. However, the value of *C. macrostachyus* mean root collar diameter was significantly (p=0.05) lower than those of C*. africana* and *M. ferruginea.*

Similar to *C. africana,* tips of sixteen young trees *of C. macrostachyus* dried. Later they developed new leading shoots. These may produce multi-branched trees. Marked decline in the relative growth rate for height (RGRH) of *C. macrostachyus* was observed from November to January (Fig. 5). It is concluded that similar factors that induced shoot die back in *C. africana* have been responsible for shoot die back in *C. macrostachyus.*

The overall RGRH of *P. falcatus* was significantly (p=0.05) lower, compared to the other three tree species studied (Fig 5). It has been proposed that late-successional species begin to accelerate their growth after one year. They require a longer establishment period than early- successional species (Davidson *et al.*, 1998).

The value of mean root collar diameter (RCD) of *C. africana* was significantly higher (p=0.05) when compared with the other tree species. *M. ferruginea* stood second with respect to RCD. *C. macrostachyus* and *P. falcatus* were with values which were not significantly different from each other. Even though the difference in RGRH of *C. macrostachyus* and *C. africana* was not significant, *C. africana* attained significantly (p=0.05) higher value of RCD, thus contributing to its overall growth performance. In the current study, differences in the RCD of the four young tree species augmented data on their growth performances.

The overall survival percentage was high in all the four indigenous tree species. Morphological and physiological conditions of the species and care taken (mulching, watering, addition of manure and protection from being browsed) for the seedlings could be some of the reasons that may have contributed for the high survival percentage. For example, the reorientation of leaves of *M. ferruginea* to avoid direct solar irradiance, along with its capacity for fixing nitrogen, may contribute to its high survival percentage. Jiregna Gindaba *et al.* (2004) mentioned M. *ferruginea* as a good candidate for drier areas. Earlier studies have shown that planted seedlings survival in the field is the integrated result of physiological and morphological attributes, as well as management practices (Evans, 1972).

It is interesting to note the high survival percentage of *C. africana*. Out of 88 seedlings only one seedling died and the death was due to human interference. The seedlings were able to survive and grow even under the hottest and driest times of the study period. Similar survival percentage of *C. africana* (92.23 %) was reported by Mebrate Mihretu and Belachew Gizachew (2004), despite differences in the soil and climatic conditions between the study sites of these workers and the current study.

The capacity of *C. africana* to close its stomata during and around midday and under water deficit conditions has been reported by Legesse Negash (1992). On top of this, there were no browsed seedlings of *C. africana* during the study period. Browsing damage could affect the survival percentage of the seedlings (Osukjoya *et al.,* 1992; Cadenasso and Pickett, 2000). It is therefore concluded that efficient stomatal control, coupled with the drought deciduous of the species, have contributed to the trees high survival percentage.

Similarly, the high survival percentage of *C. macrostachyus* (99.43%) may be associated with drought induced leaf shedding behavior, along with its capacity for closing its stomata under water deficit conditions. In the events of severe water stress, both *C. africana* and *C. macrostachyus* shed their older leaves and minimized the surface area of their younger leaves drastically. (Legesse Negash, 1992). Unpalatability of *C. macrostachyus* to avoid herbivory may also contribute to its survival (Dechassa Jiru, 1999).

P. falcatus was found with the highest survival percentage (100 %) and this agrees with its high stomatal resistance, minimizing water loss during drought, which is important for survival (Legesse Negash, 1992).

Summer drought is known as the main cause of mortality of seedlings (Castro, *et al.*, 2005). During the study period, water was supplied to minimize the problem, thus this may also increase the survival percentage of the studied young trees.

Only one seedling of *P. falcatus* was browsed (0.39%). In a study made by Getachew Tesfaye *et al.,* (2002) on eight species, *P. falcatus* was mentioned as the only species that was not browsed. This condition also contributed for the survival of *P. falcatus.*

About 5.33% of *M. ferruginea* seedlings were browsed. When compared with the other three indigenous species, this was the highest significant value (p=0.05). Damage came mostly from cattle sneaking into the experimental site. Young plants of *M. ferruginea* were seen to be very palatable to cattle, possibly because of their soft and green leaves. This indicates that there is an association between the rate of herbivore damage and palatability of species. This was noticed by Getachew Tesfaye *et al.* (2002).

Herbivore damage was not a problem for *C. macrostachyus*. In this study, only one seedling (0.30 %) was browsed. Dechasa Jiru (1999) reported the unpalatability of *C. macrostachyus* and the importance of this feature to protect it from being browsed by farm animals.

Distance from the edge affects herbivore damage (Cadenasso and Pickett, 2000). High herbivore damage of the studied seedlings in sub plots 1, 2 and 3 was due to the location of these sub plots to the entry point of the cattle that grazed around the experimental site. Had it not been for the fence of thorny shrubs such as *Carissa edulis* (forssk.) Vahl, and employment of herdsmen for warding off the cattle from damaging the young tree seedlings, the data presented in this thesis could not have been produced.

When the soil of Tulu- Korma was correlated with the reference for rating physical and chemical properties (London, 1984), it was with medium pH, low nitrogen, low organic carbon and very low available phosphorus. The texture of the soil was found to be clay (67 % clay, 22% silt and 11% sand) (Table 3). The value of its bulk density showed that it was previously used as a farmland. The land had previously been used to produce tef.

Growth of tree seedlings (in reforestation processes) at a site could be fast or slow depending on the degree of previous land use effects (Mulugeta Lemenih and Demel Teketay, 2004). Fast growing broad leaved species such as *Cordia* require fertile soil and do not grow well on poor soil conditions (Evans, 1992). The growth rate of *C. africana* in this study was lower when compared with the previous reports. One of the reasons for this difference could be the poor soil condition of the study site, as well as the intrinsic behavior of the vertsol, *viz.* cracking during the dry season and waterlogged during the rainy season. These are well-known features of clay soils (London, 1984; EARO, 2000*).*

6. CONCLUSION AND RECOMMENDATIONS

1. The result of this study indicated that the four young indigenous tree species, *vis. C. africana, C. macrostachyus, M. ferruginea* and *P. falcatus* were significantly different (p = 0.05) in their relative growth rate values.

2. *C. africana* and *C. macrostachyus* followed *M. ferruginea* in their overall relative growth rates. The mean RGRH values of *C. africana* and *C. macrostachyus* were not statistically significant (p= 0.05). However, the value of mean root collar diameter of *C. macrostachyus* (0.87 cm), is lower when compared to mean root collar diameter of *C. africana,* which attained the highest significant (p=0.05) value in its RCD.

3. The overall survival percentage of the indigenous tree species was very high: 100 % for *P. falcatus,* 99.43 for *C. macrostachyus*, 99.34 for M. *ferruginea* and 98.86 for *C. africana.* Herbivore damage was observed in all the young tree species, except for *C. africana.* Herbivore damage was highest in *M. ferruginea.*

4. Currently, indigenous trees of Ethiopia are declining at an alarming rate. For example, now days less than 1% of the original podo has remained. Thus, such a high survival percentage as seen in the study could be a promising condition for the reestablishment of indigenous tree species.

5. Millions of seedlings are reported to have been planted every year by peasant and urban dwellers associations and the state. However, many of these seedlings fail to grow. As a result resource, labour and time are wasted for nothing. Thus, Special attention should be given for the successful establishment of indigenous tree species. A good management that includes watering, protection from herbivory or other damaging agents, coupled with effective operational inputs (mulching, and adding manure) would help the establishment of young indigenous trees on a given site.

6. It is also necessary to plan and implement practices that would enhance the reestablishment of indigenous tree species. This study recommends further work on the growth performance of Ethiopia's indigenous tree species.

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8. APPENDICES

Appendix. 1

Seedling height measurements (every 45 days) and RCD (cm), at the last measurement of height.								
	tree-no.	**h_1**	**h_2**	**h_3**	**h_4**	**h_5**	**h_6**	**RCD**
C. africana	1	52	57.4	59	60	64.2	68.3	2.8
plot one	2	28	32.1	34	35.6	36.1	43.1	1.7
1	3	52	53.5	55	57.8	74.1	100.6	2.3
1	4	41	44.9	48	55.5	63.6	78.3	2.7
1	5	42	45	46.1	46.8	47.1	49.2	1.5
1	6	38	45	49.9	54.8	56.4	57.7	2.3
plot two	7	54	57.5	60	61.4	62.8	68.4	4.2
1	8	51.2	56	59.9	75	96.5	131.2	3.4
1	9	45.5	50	52	53.2	66.3	90.7	3.1
1	10	57.5	60	62	75.6	81.2	93.8	3.5
1	11	32	36.4	39	40.5	44.5	56.5	2.4
1	12	35	40.5	43	47.3	48	49.6	1.7
1	13	42.5	50	56.9	62	71.4	80.8	2.7
1	14	45.5	48	50.9	72.8	88.6	101.2	4.6
1	15	36	38.9	48	69.8	92.2	110.8	3.6
1	16	47	47.5	48.5	50.9	54.2	74.2	3
1	17	43	47	48.5	52.4	60.2	76.5	3.4
Plot three								
1	18	37	41.8	48	61.5	85.2	93.2	3.4
1	19	48.5	50.2	57	58.4	59.1	60.2	3.2
1	20	42	43.6	52	58.1	65.6	89.3	3.2
1	21	30.5	36	43.5	47.9	49.6	58.4	2
1	22	40.5	47.5	50	51.2	51.6	53.2	1.6
1	23	36	38.3	41.5	44	44.6	47.4	2.2
1	24	45	49.1	59.6	64	71.1	79.3	2.6
1	25	18	23.6	26	27.8	32.4	38.7	1.5
1	26	48	49.5	53.5	56	61.6	79.3	2.6
1	27	38	47.9	62	69.8	88.3	105.3	3.6
1	28	49	51.5	59	62.1	64.5	71.3	2.4
1	29	42	47.3	50	56.8	64.5	90.6	3.1
1	30	38	43.7	48	55.9	77.4	107.4	3
1	31	20	25.3	30	32.9	39.8	60.4	2.5
plot four								
1	32	40	42	45.5	47.7	56.2	75.9	2.9
1	33	40	43.4	46.2	54	76.3	91.6	2.7
1	34	45	49	53.9	56.1	60.3	69.4	2.7
1	35	32.5	38.5	43.4	49	57.4	80.3	2.4
1	36	43	47.5	53	55.9	66.2	74.2	2.1
plot five								
1	37	22	26.7	30	33.3	39.4	45.3	2.1
1	38	18	23.1	30	35.9	45.2	60.6	2
1	39	27	31.4	35	37.5	38.1	46.8	1.9
1	40	39	45	49	53.3	60.6	65.3	2.2
1	41	44	47.6	50	56.9	57.2	58	1.8

1	42	24.5	30.2	33	38	40.3	50.3	2.1
1	43	23	29.5	30	34.9	40.5	48.6	1.6
1	44	17	22.1	25	27.7	30.2	45.2	1.1
1	45	30	32.5	34	39.2	42.1	48.4	1.2
1	46	18	20.3	22	24.4	30.1	31.4	1
1	47	44	47	48.5	52.9	54.4	56.5	1.6
1	48	28	33.6	36	40.8	41.5	43.7	1.3
1	49	27	31	32.4	35.9	44.7	74.4	2.3
1	50	14	18.5	25	29.1	42.1	56.6	2.8
1	51	13.5	18	24	25	28.9	29.8	0.8
Plot six								
1	52	13	16.5	23	25.6	28.1	28.4	0.9
1	53	40	43.1	46	48.6	50	50.6	1.4
1	54	44	48	56.1	57.5	60.1	61	1.1
1	55	42	44.5	44.9	45.1	45.3	45.7	1.2
1	56	22	25	28	31.8	32.3	32.6	1.4
Plot seven								
1	57	48	49.8	51	52.8	53.4	53.7	1.3
1	58	39.5	44	47	48.1	50.8	78.4	3.1
1	59	29	34	49.6	58.7	78.2	97.6	2.9
1	60	37	55.5	65	70.1	74.4	86.4	3.2
1	61	55	58.5	61.2	62	62.4	62.9	1.8
1	62	41	45	46	46.5	46.6	47.8	1.5
1	63	32	37	38.9	41	46.3	64.6	1.7
Plot eight								
1	64	20	26.5	34.2	42	59.1	83.6	3.1
1	65	22	26.5	37	46.8	66.7	97.8	3.5
1	66	43	47.5	60	62.1	65.2	69.6	2.7
1	67	24.5	30	33	35	36.1	38.2	1.5
1	68	36	42	49	51.2	53.6	54	2.6
1	69	35	37.8	41	42.8	45.3	45.9	2.1
1	70	14	19.5	28	29.1	32.6	46.6	1.9
1	71	50	52.5	57	58.1	58.5	58.8	2.2
1	72	55	56.1	59	60.1	60.7	63.4	1
1	73	63	66	70	71.2	72.3	72.8	2.5
1	74	41	45.5	48	50.5	50.7	51.2	1.5
1	75	36	42	48	51.5	52.6	54.4	1.7
1	76	40	43.7	45	46.1	46.5	57.6	0.5
C. macrostachyus								
plot one								
2	1	17.6	22.4	23	23.6	24	24.5	0.2
2	2	14	16.1	18.5	18.7	21.2	32.1	0.6
2	3	43	47.5	50.7	54.5	58.3	62.4	1.6
2	4	26	28.5	30.3	30.9	36.9	37.1	1
2	5	32	33.5	36	39.2	41.1	46.2	1.3
2	6	14	18	20.5	21.4	23.5	24.1	0.3
2	7	36.1	39.2	41.4	42.3	54.2	58.2	1.2
2	8	21.9	25.1	26	27.5	32.4	35.6	0.7
2	9	14.3	17.2	19	25.4	40.6	45.3	1.1
2	10	14.2	16	18.5	21.4	27.3	35.2	0.9
2	11	14	18.5	20	29.6	43.2	57.4	1.5
2	12	33	33.5	36	40.2	46.4	58.2	2.3
2	13	25	28.9	30.5	31.4	40	46.3	1.2
2	14	24.2	27	28.5	30	33.1	35.6	0.6
2	15	19.9	22	23.1	24	28.4	31.2	0.9
2	16	19.1	19.5	20	20.5	24.8	25.1	0.5
2	17	9.8	12.5	14	14.9	22.4	29.2	0.7
2	18	26.2	29.9	30.9	31.1	36.7	43.3	1.2

2	19	9.8	15.1	19.5	22	30.2	34.1	0.8
2	20	11.5	15.2	17.5	23	29.4	32.7	0.6
2	21	19.1	23	25.6	26.9	33.3	36.2	0.7
2	22	15.5	19.5	21	24.4	26.6	28.4	0.4
2	23	17.5	24.1	26	27.9	31.2	33.1	0.4
2	24	13.9	17.4	21	23.5	25.3	30.2	0.4
2	25	35.5	38.5	40.6	47	64.2	71.6	1.6
2	26	15.5	17	19.3	20.4	29.9	32.2	1
2	27	18.1	20	21.2	25	30.6	32.2	0.5
2	28	8.8	13.2	15	16.2	23.4	30.1	0.3
2	29	17	19.1	20.5	22.4	27.6	32.4	0.3
2	30	28.1	31	31.5	33.5	37.7	40.6	0.8
2	31	46.5	49	49.5	51.5	52.1	53.2	1.4
2	32	15.9	19.5	20.1	20.5	23.7	31.2	0.6
2	33	13.5	17.8	20	23.3	27.4	31.2	0.6
2	34	35.1	37.5	40	40.5	40.9	43.1	1.3
2	35	37.7	40	41.5	44	44.7	51.2	1.1
2	36	27.5	30.3	32.1	34	36.9	41.6	0.8
2	37	16.3	19.5	21	21.5	23.7	27.3	0.3
2	38	21.5	23	24.5	29.3	34.4	38.1	0.7
2	39	11	12.5	14.5	15.1	19.9	30.6	0.8
2	40	10.5	12.2	12.5	13	20.3	22.4	0.7
2	41	28.5	32.2	33	34.3	35.2	37.3	0.8
2	42	11.5	15.5	20.6	25.1	33.3	36.6	0.7
2	43	22.5	27.3	28	29	34.4	40.7	0.8
2	44	24.5	25.5	26	27.8	33.7	42.4	0.9
2	45	15	19.5	20.2	21.1	33.5	49.6	1.4
2	46	10.8	14.2	16.3	16.9	22.3	25.4	0.6
2	47	37.9	41.4	42	42.5	43	46.4	1.2
2	48	13.5	16.3	17	18.3	27.5	36.7	0.8
2	49	14.1	18.6	22.2	25	32.2	37.3	1
2	50	15.5	18	21.1	27.4	32.4	45.2	1.3
2	51	18.9	20	23.2	25.3	34.8	43.2	1
2	52	15.1	19.2	23.5	29.7	53.1	59.3	1.2
2	53	14.5	17.3	20.4	22	24.3	30.1	0.7
2	54	12.2	15.3	24	39.7	50.2	53.6	1.8
2	55	12.9	20.5	26	30.3	48.6	73.2	1.9
2	56	35.8	38	41.5	43.5	53.6	58.4	1.7
2	57	18.5	21.2	22.3	26	27.2	33.4	0.9
Plot two								
2	58	13.5	15.2	19	22.9	37.9	52.3	0.9
2	59	10.7	13.5	15	18.3	29.7	48.6	1.1
2	60	19.1	24.3	28	35.2	49.4	65.2	1.6
2	61	15.5	20	22.8	29.1	48.6	70.3	1
2	62	9.5	14.5	15.5	16.3	21.3	25.4	0.3
2	63	23.9	27.4	29.8	31.5	35.2	42.3	0.6
2	64	13.5	16	20.9	22.3	27.8	30.7	0.7
2	65	12.1	15	17.9	18.8	19.6	24.6	0.3
2	66	24.5	25	26	26.8	27	28.4	0.4
2	67	10.5	14.2	20	23.5	34.3	46.8	1
2	68	12.1	15.5	19	20.8	27.7	38.3	0.9
2	69	30.7	34.8	37.5	38.5	43.8	44.2	1
2	70	30.5	32.1	34.5	36.5	37.9	39.2	1.1
2	71	13	17.5	24.9	26.3	30.6	37.5	1
2	72	12.5	17.5	21.7	23	31.2	39.4	0.8
2	73	19	19.5	21.5	24.1	33.6	43.8	1.5
2	74	16.9	18.3	20.5	21.7	33.4	37.6	1
2	75	21.5	23	24.8	25.1	34.3	39.4	0.6

2	76	16.5	17.3	18.4	19.1	20.1	26.4	0.3
2	77	12.1	14.3	18.2	19	29.1	39.8	1.2
2	78	18.5	21.9	23	24.9	35.6	40.6	0.9
2	79	12.5	16.5	19.3	20	25.1	27.6	0.3
2	80	21.9	23.5	24.8	25.2	25.4	28.4	0.5
2	81	30	31.5	33	33.5	34.3	41.2	0.9
2	82	20	21.5	23.5	24.6	24.9	28.6	0.4
2	83	28.5	30	32.1	32.5	33	40.6	0.7
2	84	14.1	15.3	16.9	17.2	19.9	22.4	0.1
2	85	19.8	21	23.5	24.8	26.7	30.8	0.3
2	86	18.2	21.4	25	26.7	31.4	37.2	0.6
2	87	15.5	17	19.1	20.3	29.2	33.6	0.5
2	88	12.1	12.9	13.5	14	20.2	24.4	0.4
2	89	26.1	27.3	29.8	30.6	36.3	51.4	1.3
2	90	12	16.3	19.5	20	24.8	35.2	0.6
2	91	15.5	18	21.4	27.9	37.2	54.3	1.6
2	92	13.5	15	19.1	20.1	31.2	42.4	1
2	93	14.9	17.1	19	20.8	31.3	43.6	0.8
2	94	12	13.1	16	19.5	24.7	32.6	0.9
2	95	14.9	17.3	18	20.5	27.9	37.6	0.6
2	96	15	20.6	24	31.4	48.4	62.8	1.5
2	97	25.5	28.5	31	32.5	33.1	34.2	0.8
2	98	14	18.3	21.5	23.8	26.6	34.3	0.9
2	99	20	22.5	23.2	24.1	29.2	36.4	0.7
2	100	32	37.5	39.4	43.1	44.2	48.3	1.1
2	101	17	21.8	23	27.1	39.3	48.2	1.2
2	102	21	24.5	25.8	26.7	29.8	36.6	0.9
2	103	15.1	18.3	20	21.9	22.6	26.6	0.4
2	104	22.5	27	28.6	29.2	36.7	44.8	0.3
2	105	7.1	10.3	14.5	28.8	38.6	51.2	1.6
2	106	17.5	19	21	22.2	27.8	33.4	0.8
2	107	12	16.5	21.5	24.6	35.3	43.2	0.7
2	108	22.5	23	23.5	25.2	29.4	37.2	1.2
2	109	13	13.8	14.2	14.7	21.6	28.2	1.9
2	110	28	29.7	30.5	31	35.1	48.2	1.3
2	111	13.5	17	19.5	21.4	24.4	28.7	0.7
2	112	15	17.4	22	34.1	49.2	59.4	1.7
2	113	15	16.5	18	21.2	22.6	41.7	0.4
2	114	23	24.6	26	28.9	32.8	33.4	1
2	115	12	17.8	20	26.8	42	58.7	1.2
2	116	22	24.6	26.5	33.5	50.8	73.6	1.5
2	117	14	16.5	18.5	21	24.8	33.6	1.1
2	118	11.5	15	15.8	16.9	17.8	22.2	0.3
2	119	22.8	23.5	24	24.6	28.6	32.2	0.4
2	120	12.5	14.3	15.5	16.5	22.4	26.7	0.5
2	121	15	16.2	17.5	18	18.9	24.2	0.3
2	122	11	13.4	16	19.2	24.6	31.3	0.6
2	123	13.1	17	18.1	21.1	30.3	42.2	1
2	124	16	17.9	19.2	19.8	26.6	33.4	0.9
2	125	15	15.5	16	16.3	18.3	22.4	0.1
2	126	16	17.4	19.5	23.9	27.4	30.2	0.6
plot three								
2	127	19.5	21	24	28.7	46.9	65.2	1.2
2	128	15	17.5	19	23	23.3	29.2	0.6
2	129	22	34.5	35	40	49.5	59.4	1.5
2	130	29.5	32	33	38.8	45.2	54.6	1.1
2	131	26	27	27.5	32.9	33	33.7	0.5
2	132	10	13.5	16	19.9	24.1	28.6	0.5

2	133	16.5	21	23	26.8	30.7	39.4	0.6
2	134	25.5	29.1	32	34.9	43.1	54.6	1.5
2	135	9.5	11	11.5	15	29.4	29.8	0.3
2	136	26	30.5	32.6	36	39.7	41.7	1.1
2	137	17	20.6	27.3	36.5	45.6	54.1	1.9
2	138	29	33.5	37.4	40.9	51.9	62.5	2.1
2	139	30	33.5	34	37.9	41.3	43.9	1.3
2	140	14	17.5	21	27.1	37.6	53.7	0.7
2	141	31.5	33	34.5	36.6	38.1	47.8	1.8
2	142	22	25.5	26	32	41.5	54.8	1.8
2	143	10.5	14.5	18	25.3	37.3	51.2	0.9
2	144	14	17.5	24	25.6	28.1	33.9	0.6
2	145	17.5	23.5	24	26.9	27.8	34.6	1.3
2	146	16.5	20	26.1	31	32.5	48.2	1.4
2	147	16.5	17.1	17.5	17.7	21.2	34.7	0.5
2	148	19	19.5	21.1	26	26.5	35.3	0.6
2	149	33	33.5	34	36.6	38.8	44.6	1
2	150	21.5	26.5	28.9	35.3	37.9	45.4	1.4
2	151	13	16.7	18	19.1	26.6	36.3	0.6
2	152	16	19.4	23	25.9	28.1	34.3	0.5
2	153	15	18	19.6	22.1	25.4	32.4	0.9
2	154	30	34.5	37	44.1	44.6	47.6	0.6
2	155	20.9	24	24.5	29	33.5	39.4	1
2	156	6	9	10.5	13.9	16.8	24.6	0.3
2	157	11	14.3	16.2	20	33.4	40.3	0.9
2	158	14	16.5	18.5	24	33.8	43.8	0.8
2	159	27	30	31.4	34.9	35	41.5	0.7
2	160	16	18.5	20.5	23	34.6	45.6	0.8
2	161	22	26.5	27.1	29.9	31.3	33.6	0.7
2	162	29	31	31.5	35.1	40.9	46.7	0.6
plot four								
2	163	33.5	37.5	42	48.2	54.1	76.8	1.5
2	164	21.5	26.5	27.2	30	36.8	41.4	0.8
2	165	11	14.9	15.5	18	20.6	22.3	0.3
2	166	28.5	29.1	30	32.1	35.5	42.6	1.1
2	167	22	26.5	27.1	30	37.2	46.2	1
2	168	40	42.3	43.1	45.5	46.2	52.4	1.7
2	169	33	34.5	36	40.9	44.7	50.4	1.4
2	170	18.5	21.2	23	29.8	30.3	31.9	0.9
2	171	29	33	33.5	37.8	38.1	39.1	1.1
2	172	28.5	32.8	33.5	38.3	38.6	42.3	0.6
2	173	18.5	20	21.6	29.4	33.6	38.6	1.1
2	174	13	15.4	17	23.8	33.7	44.2	0.9
2	175	18.5	21	21.5	24.6	29.4	33.1	0.7
2	176	23	26.3	27	32.9	36.6	46.6	1.1
2	177	16.5	18.6	20	22.8	25.2	30.7	0.4
2	178	13.5	17.8	19.1	21	23.2	29.7	0.6
2	179	14	18	18.5	20.5	27.8	44.4	0.8
2	180	18.5	25.5	27	29.8	33.8	37.6	1.6
2	181	16	19.5	20	25.1	27.2	36.4	0.7
2	182	16.5	17.5	18	19.1	30.3	37.3	0.9
2	183	14.5	19	19.5	23.7	35.8	44.6	1
2	184	17.5	18.5	19	26.1	28.2	34.4	0.6
2	185	10	14.2	15.1	18.9	28.2	35.7	1.1
plot five								
2	186	30.5	31.1	34	35.9	36.2	43.4	1.3
2	187	26.5	30.3	33.5	39	40.1	43.1	1
2	188	24	25.2	27	32.5	34.7	38.7	0.6

2	189	26	29.3	30	34.5	40.6	52.4	1.7
2	190	19.5	21	21.5	26.1	26.7	26.9	0.4
2	191	31	36.4	38.3	39	40.1	42.6	1
2	192	19.1	19.5	20	20.3	24.1	24.6	0.3
2	193	27.5	29	32	37.1	38.7	39.8	1.3
2	194	27	32	32.5	35.1	35.9	38.6	1.2
2	195	14	17.5	19.3	24	24.5	28.2	0.7
2	196	13.5	15	16.5	19.1	19.4	26.2	0.3
2	197	16.5	19	22.5	30.8	31.2	31.4	0.5
2	198	17	20	20.5	21.9	23.6	26.2	0.3
2	199	8.5	11	15.5	19.8	20.1	22.6	0.5
2	200	18	19	20.5	26.9	27.5	30.4	0.4
plot six								
2	201	25	27.2	28.3	29.5	35.9	39.1	0.6
2	202	19	20	20.8	21.3	22.5	27.8	0.5
2	203	30.5	31.1	32	34.6	41.6	44.1	1.2
2	204	35	39.4	40	41.2	43.3	46.1	1.3
2	205	17.5	18	19.5	21.2	25.6	32.9	0.4
2	206	15.5	19.5	20.5	22	29.3	33.1	0.5
2	207	14	16	19.7	20	28.1	30.2	0.6
2	208	28	30.6	31.2	31.5	31.6	32.1	0.7
2	209	25	29	30.3	30.8	33.7	35	0.7
2	210	26	29.1	29.7	30.1	38.3	43.9	0.8
2	211	26	28.3	29.5	30	30.5	33	0.7
2	212	21	23	23.8	24.2	26.7	32.1	0.7
2	213	18	19	20.9	21.8	23.5	32.9	0.5
2	214	32	33	39.6	40.2	42.2	46.8	0.8
2	215	23	25.8	27.4	28	30.3	34.8	0.5
2	216	10.5	13.5	14	14.4	19.6	20.1	0.1
2	217	32.5	34.1	34.9	35.4	39.5	44.1	0.6
2	218	10	13	14.6	15	20.5	21.5	0.4
2	219	14.5	15	17.1	17.8	24.7	32.9	0.7
2	220	28	29.5	32.8	33.1	33.4	33.9	0.8
2	221	11	13	15.4	16.6	20.4	24.9	0.3
2	222	24	24.3	24.5	25.1	25.3	31.8	0.3
2	223	20	21	22.5	25.3	25.6	26	0.5
2	224	17	21.5	25	26.3	27.4	29.9	0.3
2	225	25.5	32.9	36.2	38	38.5	39	0.6
2	226	17.2	18.6	19.5	20	26.7	27.9	0.5
2	227	23.5	24.9	25.3	26.6	27	27.4	0.4
2	228	20	24.3	26	26.6	30.2	30.8	0.5
2	229	20	22.7	24.6	25	33.6	35.9	0.8
2	230	15.5	18	18.7	19.2	27.3	33.1	1
2	231	19	21.9	25.1	26.4	34.8	38.1	0.6
2	232	28	31.7	32.8	33.1	33.2	34	0.6
2	233	26	28.8	29.4	30	32.3	34.1	1
2	234	26.5	27	28.6	29	29.8	30.2	0.6
2	235	28	32	33.5	34.2	35.2	38.1	0.5
2	236	27	29.9	32	33.2	34.4	38.1	1.1
2	237	17	20	25.8	26	32.8	49.8	1
2	238	23	26.5	27	28.4	30.3	31.1	0.6
2	239	11	12.9	17.1	18.6	30.1	38.9	0.9
2	240	32.5	33.7	34.3	34.5	40.3	42	1.3
2	241	10	11.8	17	19.1	28.4	30	0.5
2	242	21	25.3	29.6	30	36.8	42.9	0.7
2	243	16.5	18.5	25	26.7	37.8	48.1	0.6
2	244	34	35.1	35.6	36	36.1	37.2	0.8
2	245	17	19.5	20	21.1	21.5	28.8	0.4

2	246	17	18	18.3	19	23.2	28.1	0.4
2	247	15	15.5	19.1	20	20.5	36.9	0.8
plot seven								
2	248	32	34.5	37	39.8	46.3	56.1	2
2	249	29	33.5	38.6	39	43.2	46.1	1.4
2	250	20	22.5	25.4	26	27.8	38.8	0.8
2	251	24	25.3	27	28.1	34.2	36.1	1.2
2	252	20	23.1	25	26.2	28.6	32.1	0.7
2	253	17.5	20	20.5	21	22.1	22.5	0.3
2	254	32.5	35.9	36.6	37	38.3	41.1	0.6
2	255	19	22	25.5	26.4	39.2	52.1	1.2
2	256	24.5	29.3	31.6	32	33.4	34.1	0.7
2	257	31.5	32	32.4	33	37.9	39.2	0.6
2	258	8	9.6	12.1	13	17.8	24.8	0.8
2	259	16.5	18	20	21.2	24.1	24.5	0.6
2	260	12	12.5	15.6	16	18.7	19.9	0.4
2	261	18.5	20.5	25.1	26.5	36.4	43.1	1.3
2	262	17	18	22.1	23	24.3	25.1	0.3
2	263	19	21.3	23	24	24.4	25	0.4
2	264	15	17.6	20	22.6	32.3	39.9	1.1
2	265	36.5	40	45.9	46.9	48.1	52.9	1.6
2	266	15	18.5	22.6	23.9	24.8	26.1	0.3
2	267	32.5	34	35.8	37	37.4	39.1	1.2
2	268	26	27	32.9	33	38.6	46.8	1.4
2	269	27.5	30	32.4	33	35.2	39.9	1.1
2	270	26.5	29	31.8	32.4	34.4	36.1	1.2
2	271	36	40	41.3	45.8	59.6	70.2	1.7
2	272	34	37	40.8	41	41.6	43.1	1.3
2	273	22.5	23.5	28.5	29.1	30.1	35.2	1
2	274	38	42.5	45.1	46	48.1	58.9	1.6
2	275	25	26.5	27.2	27.9	30.6	34.1	0.6
2	276	29	30	32.9	33.3	33.8	34	0.4
2	277	10	13	13.6	14	18.4	20.1	0.3
2	278	26	26.5	30	32.1	35.8	39.2	0.6
2	279	21	22	22.7	23	23.8	25.5	0.4
2	280	24.5	29.5	30	31.1	37.6	40	0.3
2	281	26	28.5	29.5	30	31.7	33.1	0.4
2	282	30	34.9	36.2	37	39.5	40	1.3
2	283	19	21.3	22.7	23	24.3	29.3	0.4
2	284	16	20	24.1	25	26.4	30.1	0.6
2	285	10	14	14.5	15	17.3	27.8	0.1
2	286	44	48	49.5	52.4	71.1	79.7	2
2	287	42	45	45.6	46	54.5	56.1	1.7
2	288	40.5	43	44.3	45	49.8	53	1.8
2	289	23.5	27.8	28.4	29	41.2	51.1	1.5
2	290	29	31.5	32.5	33	34.4	49.8	2.1
2	291	28.5	31.4	33.6	35	46.2	50.1	1.2
2	292	16	18.5	21.5	23.9	28.1	29	0.7
2	293	20	24	26	27.5	28.8	29.3	1
2	294	23	24	26.3	27	27.6	29.8	0.4
2	295	31.5	33.5	35	35.4	37.7	40.9	1
plot eight								
2	296	21	22.9	25	26.8	28.7	38.4	0.6
2	297	24	24.9	26	29.8	31.4	36.7	1
2	298	32	32.8	36.9	38	41.6	53.7	1.5
2	299	33.5	35	38	39.1	43.4	48.6	0.9
2	300	30	32.5	36	37.1	45.6	61.9	1.5
2	301	26	26.8	28	29.2	32.2	37.8	0.4

2	302	27	30.5	33	33.5	33.7	33.8	0.9
2	303	14.5	17	18	19.1	24.6	27.6	0.3
2	304	43.5	47	50	53.7	64.3	64.5	1.4
2	305	10.5	13	16.9	20	27.6	34.4	0.8
2	306	21	26.1	28	29.5	30.1	30.4	0.7
2	307	58	63	70	73.7	76.4	90.6	3.8
2	308	42.5	44.8	47	48.3	51.5	65.7	2.1
2	309	17	21.1	24	25.1	30.8	41.4	0.8
2	310	32.5	35	43	54.8	59.4	74.6	2.7
2	311	27	29	30.4	33.5	33.7	35.3	0.7
2	312	23	26	29.2	30.9	33.5	33.9	0.2
2	313	15.5	19.1	22.5	23.5	24.4	41.4	0.3
2	314	32.5	37	38.5	43.1	47.6	51.7	0.7
2	315	32.5	33.1	34	35.1	39.8	43.2	0.6
2	316	22	26	26.5	27.2	31.1	36.2	1.1
2	317	15.5	16.5	17	18.9	19	20.4	0.4
2	318	30	33	34.5	36.2	37.1	40.3	0.9
2	319	23	25.1	26	26.8	29.8	30.8	0.4
2	320	22	24	24.5	26.8	28	30.5	0.4
2	321	29	31.5	34	37.2	40.1	45.7	0.7
2	322	40	43.9	44.5	46.1	55.1	59.6	1.4
2	323	28	29.8	31	32.5	33.1	33.6	0.3
2	324	32.5	36.8	38	40.1	44.5	47.6	0.6
2	325	28	29.9	31	33.2	33.6	33.8	0.3
2	326	21.5	23	24	26.5	27.9	28.4	0.5
2	327	39.5	43	46	47.1	52.8	53	1.1
2	328	36	39.9	41	42.5	45.6	58.6	1.1
plot one								
M. ferruginea								
3	1	18	21	22.5	23.1	27.8	37	0.6
3	2	29	32.5	39.5	40.2	58.6	63.6	1.5
3	3	14	17	20	24.4	41.5	50	1.2
3	4	34.5	38	40.5	53.2	76.1	77	1.6
3	5	14	21	24	29.4	54.6	75	1.2
3	6	27.5	30	34	42.3	52.9	64	1.7
3	7	33	37	40.5	48.8	61.2	85	2.1
3	8	26.5	28	30	33.6	42.8	47	1.1
3	9	33.8	37.3	40.1	43.7	45.6	48.5	1.3
3	10	26	31	35.5	36	50.1	66	1.4
3	11	32.5	34	37.5	40.2	51.9	70	1.3
3	12	30	31.5	33.5	38	60.6	85	1.9
3	13	20	21.5	23.5	28	37.5	40	1
3	14	19	20	23.5	27.1	33.4	35	1.1
3	15	27	29	31.5	33.2	34	35	1.1
3	16	16.1	17	18	20.5	21.3	29	0.8
3	17	16	18	18.5	21.7	22	29.1	0.6
3	18	22.5	28.5	31.5	33.8	34	34.5	0.9
3	19	11.5	12.5	13	15	18.2	20	0.5
3	20	28.5	32.5	38.5	49.3	65.2	95	2
3	21	30	31	35.5	38	40.3	59	1.9
3	22	20	22.5	23.1	23.7	24.2	25	1.1
3	23	20	23	24.5	25	28	30	0.6
3	24	12.5	16	17	19.8	24.9	29	0.9
3	25	39	41.5	52.5	64.1	78.2	82.5	2
3	26	35	38	39.5	42.6	51.9	61	1.9
3	27	11	15	19	26	43.4	58	1.1
3	28	19.5	24	26	27.2	33.9	43	1.3

3	29	37.5	41	46	47	59.8	68.2	1.8
3	30	12	13	15	16.8	21.4	24	0.6
3	31	34.5	36	37	37.5	49.8	65.1	1.1
3	32	25.5	28	30.5	38.9	60.2	75	1.2
3	33	18.5	24	26	30	36.2	44.5	0.8
3	34	24.5	36	40	46.6	58.2	78.5	2.1
3	35	12	14	16.5	17.1	23.1	30.1	1.1
3	36	15.5	20	26	33.6	50.2	67	2.1
3	37	20.5	27	30.5	34	53.4	60	0.9
3	38	29.5	37	39.5	46.2	68.6	86	1.9
3	39	26	28	30.5	31.3	38.1	42.1	1.4
plot two								
3	40	32.5	37	40.5	44	52.1	59	2
3	41	8.1	11	13.1	15	17.5	27	0.9
3	42	25	32	33.5	36	54.1	74	2.2
3	43	14	18	19.5	20	33.2	49.1	2.1
3	44	17.5	20	22	25.1	29.7	41	1.9
3	45	23.5	28.2	30	34.8	38.3	50.1	1.1
3	46	24	28	33	38.7	42.6	44	1.8
3	47	19.5	28	29.5	30.1	31.1	33	1.3
3	48	34.5	39	40	41.2	49.2	62	1.1
3	49	21.1	27.2	30	32.1	38.4	45	1.5
3	50	21.5	24	28	30	46.8	61	1.9
3	51	30	36	38	40.6	48.4	60	1.3
3	52	19	22.3	25	29.8	52.1	80.1	2.1
3	53	45	49.5	56	64.2	75.4	112.1	3
3	54	32	37	41.2	42.3	52.8	62.7	2.2
3	55	31.5	35.2	39.6	43	59.3	71.9	2.5
3	56	24.1	30	36	39.4	51.9	60.9	2
3	57	12	19	23	25.9	40	47.1	1.9
3	58	12	15	16.5	18.8	28.1	37.9	1.1
3	59	28	34.1	36	45.7	55.6	71.8	1.6
3	60	12.5	18	20	26.2	44.5	48.1	1.4
3	61	40.6	45	51.5	52.8	67.3	80	1.8
3	62	31	37	43.5	50.6	67.4	79.9	1.8
3	63	28	32	34	42.1	53.2	70.1	2
3	64	18.5	22	25	25.5	35.8	39.9	1.5
3	65	18	23.5	27	27.8	28	35.1	1.9
3	66	13	18	19	21.9	24.4	31	1.2
3	67	12	16.1	19	19.5	25.8	49.1	1.2
3	68	27	31	33.5	34	34.2	34.8	0.9
3	69	17.5	24.5	28.5	30	38.1	47.2	1.9
3	70	27	31.1	35	36.8	49.8	64.1	1.9
3	71	40.5	46.5	53.5	69.8	83.1	100.5	2.9
3	72	37	42.8	48	53.1	70.8	82.1	2
3	73	35	39	43.5	47.1	49.1	50	1.7
3	74	44.5	50	53	57.8	72.7	75	1.9
3	75	19.5	23	26	27.5	34.3	36	1.2
3	76	18	22	28.5	28.8	40.9	51.5	1.2
3	77	17.1	25.1	29.5	34	46.4	60	1.9
3	78	33	36	37	41.1	45.8	55	2
3	79	24.5	33	36	41.8	43.7	64.1	1.9
3	80	34	42	46.5	47	60.8	62.5	1.5
3	81	22	27	32.5	43.1	58.6	79	1.9
3	82	29.5	34.5	35.5	40.8	54.4	77.1	2
plot three								
3	83	20.5	25	29	31.2	50.2	55.1	1.1
3	84	15	19	28.5	34	54.6	65.5	1.5

3	85	16.5	22	27.1	29.8	36	40	2.2
3	86	15	16.5	20	22.9	28.2	42	1.4
3	87	14	21	23	29.9	45.3	58.1	1.4
3	88	9.1	12.2	17	18	24.2	31.9	1.4
3	89	11	16.5	20	23.1	32.5	33.1	1.5
3	90	21.5	28	33	34	34.5	35.9	1.1
3	91	9.5	14	19	20.9	27.2	39.1	1
3	92	28	34	37	46	48.1	61.3	1.9
3	93	20	23.5	25.1	26	28.2	30.1	1.6
3	94	19	24	27.5	29.9	33.3	37.1	1.1
3	95	19.5	28	37	41.5	53.7	59.9	2
3	96	28	30	33.5	37.6	62.2	84.1	2.1
3	97	31	38.5	43	44.1	50.6	61.9	2
3	98	22.5	28.5	30	36	47.8	50.1	1.9
3	99	14	15.2	16	17.1	27.2	42.9	1.1
3	100	19	22.3	26	31	43.2	50.1	1.8
3	101	5.5	7.7	9	11	11.5	15.7	0.5
3	102	22.5	24	26	28.2	32.1	35.1	0.9
3	103	17	25	27	29.9	36.4	42.9	1.2
3	104	30	35	36.1	39	50.7	52.1	1.4
3	105	29	35	41	43.7	69.2	90.1	2.2
3	106	10	14	18.5	22.4	29.1	39.9	1.1
3	107	14	16.5	18.2	19.1	25.4	30.1	1.1
3	108	29.5	32	34	41.9	61.7	78.9	1.2
3	109	15.5	17	19	20.1	21.3	25.9	0.9
3	110	10.5	15	17	17.7	18.1	24.7	0.7
3	111	13	15.5	17	23	27.2	30.1	1.1
3	112	26	31	34	40.7	56.2	66.1	1.9
3	113	26.5	37	38	42.8	55.1	61.9	1.8
3	114	24.5	30.1	35	40.1	61.5	72.1	1.9
3	115	31	37	39.2	49.8	64.1	77.9	2
3	116	20.5	25	27	30.1	46.7	51.3	1.9
3	117	24	28.5	32	33.9	53.6	69.8	2.1
3	118	23	31	32.2	35	46.6	61.9	1.9
3	119	24.5	32	33.4	40.1	55.1	58.1	2.2
3	120	10	13	15	17.3	20.6	26.5	0.9
3	121	27	30	32	37.5	48.1	59	1.3
3	122	31	37.5	42	50	70.2	88.1	2
3	123	17	22	26	27	27.5	36.9	1.8
3	124	18	23	29.9	38	59.9	69.1	1.8
3	125	15	17	18	19.9	25.4	39.8	1.1
3	126	26.5	31	33	37	46.7	81.8	1.9
plot four								
3	127	23.5	28	34	37.5	58.4	67	2.1
3	128	13	14.5	16	20	25.8	27.1	0.5
3	129	20.5	25	29	38.5	60.3	72.1	2
3	130	23	26.1	29	31	36.4	44.9	1
3	131	39	44	52	53.1	65.6	73	1.9
3	132	9.5	13	16	19.2	24.7	29	0.9
3	133	30	34	38	40.1	55.8	68.1	1.9
3	134	19	24	28.5	36	58.3	72.1	1.6
3	135	42.5	49.5	52	60	80.1	100	2.2
3	136	23	24.5	28	35.6	52.3	56.1	1.9
3	137	22	29	30	32.1	53.4	67.1	1.3
3	138	16	19	20	29.1	38.6	52.9	1.7
3	139	27	32.4	33	44	62.6	70.1	2
3	140	24	28.5	29.5	37.4	48.8	53.9	1.7
3	141	26	30	33	37.5	47.4	69.3	1.6

3	142	15.5	20.5	25	27.1	31.2	33.1	1.1
3	143	26.5	30	31.5	33.9	49.7	75.8	1.5
3	144	16.5	21	23.5	26.9	46.2	48.1	1.4
3	145	38.5	46	55	64.1	94.4	127.1	2.1
3	146	17	23.5	33	43.1	63.7	89.9	2
3	147	18.5	23	30	40.2	46.6	74.8	1.2
3	148	23.5	29	30	34.6	48.7	58.7	1.8
3	149	14	18.5	22.5	24.8	35.4	43.5	1.4
3	150	25.5	29.5	31	38.1	51.2	64.8	1.8
3	151	32.5	35.5	39	44.1	58.3	68.1	2
3	152	28.5	33.5	36	43.2	64.3	69.2	2
3	153	24	28.5	32.5	50	62.2	70	1.8
3	154	16	20	20.5	23.9	31.2	33	1.4
3	155	32.5	41.5	43	46.1	50.7	52.1	1.8
3	156	30.5	40	42	52	65.6	92.8	2.1
3	157	17	22.5	29	34	49.9	56.9	1.8
3	158	10	13	13.5	25.4	28.2	45.8	1
3	159	24	29	31.5	35.9	49.5	63.7	2
3	160	16.5	20	21	24.1	44	46.1	1.2
3	161	27.5	29	30	40.2	52.6	68.2	2.2
3	162	25.5	30	33	38.9	54.9	86.1	2
3	163	32	36	37.5	45.6	66.2	73.1	1.8
3	164	24	25	29	30.6	40.8	54	1.8
3	165	15	20	23.5	33.8	44.3	57.8	1.4
3	166	27	32	33.3	41	61.5	65.1	1.5
3	167	26.5	30	35.1	37	53.8	57.7	1.9
plot five								
3	168	22	27	32	36.1	48.3	59.8	1.2
3	169	15.5	19	21	23.2	29.1	30.2	0.9
3	170	17	20.5	23	27.1	46.6	59.8	1.6
3	171	32.5	38	40	42.2	61.8	63.2	1.3
3	172	27.5	32.5	38	43	53.2	64.6	1.1
3	173	30	34	42	47.6	54.1	64	1.2
3	174	28.5	36	40	44.9	57.1	65.9	1.4
3	175	34.5	39	45	48.1	52.2	54.1	1.2
3	176	24.5	30	36	38.9	56.7	62.7	1.3
3	177	23	29	32	33.5	34	39	0.9
3	178	28	34	36	38.9	47.2	65	0.9
3	179	19.5	29	40	45.6	46.2	63.8	1.3
3	180	19.5	25	30	40.1	47.6	62.9	1.2
3	181	23.5	30	41	49.2	52.4	73.1	1.4
3	182	27.5	31	33	40.1	52.8	68.8	2.1
3	183	25	28	33	38.1	47.8	48.4	1.1
3	184	34.5	38	40	41.2	58.5	71	1.5
3	185	36	42	43	44.1	66.6	71.1	1.5
3	186	37.5	46	50	51.5	60.4	65.8	1.9
3	187	31.5	37	39	40.1	44.1	57.8	1.7
3	188	25.5	30	32	38.1	55.8	64.3	1.5
3	189	20	26.5	31	36.7	54.1	74.7	1.1
3	190	23.5	31	36	41.1	52.6	62.1	1.2
3	191	25.1	30	40	42.9	58.2	75.6	1.6
3	192	20	24.2	26	34.9	51.7	63.9	2
3	193	23	28	30	36.1	49.8	75.5	1.5
3	194	34	41	45	57.5	78.7	87.8	1.9
3	195	32.5	38	43	49.4	76.9	95.1	1.2
3	196	19.5	25	32	33.9	41.3	52.9	1.9
3	197	26	30	31	34.1	44.2	50.8	1.2
3	198	26	32	34	35.2	54.2	67.5	1.6

3	199	20.5	25	28	30.5	42.2	46.1	1.1
3	200	12.5	19	21	23.5	25.4	34.2	0.9
3	201	25	30	31	34.9	51.2	62.1	1.2
3	202	26.5	34	37	44.5	61.2	63.8	1.4
3	203	30	33	35	36.1	41.3	50.2	1.2
3	204	30	38	39	43.1	45.3	59.1	1.3
plot six								
3	205	37	43	46	62	76.2	91.2	2
3	206	15	20	22	23.1	38.2	49.1	1.3
3	207	25.5	30	23	39.9	56.7	74.6	1.9
3	208	19	23	27	34.1	44.2	53.9	1.8
3	209	33.5	39	40	46.8	50.3	65.7	1.4
3	210	34	41.5	45	46	59.3	62.1	1.3
3	211	33	41	42	46.1	55.7	61.3	1.6
3	212	26	29.5	31	31	49.3	55.8	1.4
3	213	30	32	33	39.1	48.7	58.1	1.2
3	214	23	28	30	36	37.4	43.8	1.5
3	215	14.5	20	21	25.5	30.6	33.2	1.2
3	216	17	22.5	25	35.1	47.9	70.2	1.3
3	217	28.5	32	33	38.1	42.2	47.1	1.1
3	218	26	30	33	35.2	52.6	53.9	1.2
3	219	22	28	31	41.7	52.9	64.8	1.2
3	220	32.5	40	41	46.2	59.8	66.2	1.5
3	221	24.5	30	32	33.1	59.4	60.1	1.2
3	222	31.5	36	43	52	69.4	82.5	1.5
3	223	20	24	26	33.9	43.2	62.8	1.3
3	224	49	54.5	60	76	101	130	2.2
3	225	30.5	34.5	36	51.1	63.8	79.1	2
3	226	17	23	26	35.9	46.1	55.2	1.4
3	227	22	27.5	33	36.9	47.6	48.5	1.3
3	228	21	23	25	26.5	32.6	39.1	1.3
3	229	21	26	29	30.1	33.6	35.5	0.9
3	230	39.5	46	49	53.3	70.9	85.2	2.3
3	231	38	39.5	42	43.1	49.7	61.8	1.4
3	232	23	27	29	32.1	43.1	53.2	2.3
3	233	19.5	25	29	30.5	35.3	66.4	0.8
plot seven								
3	234	38	42.5	44	44.9	55.4	57.1	1.9
3	235	32	35	36	37.5	51.4	56.8	1
3	236	25	29	37.5	39.1	41.2	52.1	2
3	237	19.5	24	30	31.5	44.8	63.9	1
3	238	32.5	39	46	47.9	71.1	85.7	1.3
3	239	24.5	29	36.5	39.1	46.6	70.8	1
3	240	29	36	39	40.5	61.1	67.2	1
3	241	36.5	40	43	45.3	54.6	71.8	1.1
3	242	33	39	41.5	43.1	65.2	83.1	1.1
3	243	25.5	32.5	34	36.2	40.7	42.9	1.1
3	244	20	26	29	30.1	39.7	50.8	0.8
3	245	16.5	21	25.6	27.5	39.4	45.1	0.9
3	246	34	38	40	43.2	56.2	65.2	1.2
3	247	23.5	28.5	30	31.2	41.2	50.8	1
3	248	32	39	42.1	49	66.7	89.8	1.5
3	249	26.5	33	38	41.4	61.2	71.1	1.2
3	250	26.5	32.5	35.1	38.5	54.3	65.9	1.1
3	251	26	27	28	29.5	47.9	67.6	1.1
3	252	25.5	30	34	40.4	54.4	69.9	1.2
3	253	50	55	58	59.2	72.4	74.2	2.1
3	254	30	33	38	46.9	72.8	90.3	2

3	255	24	27	30	31.5	35.7	50.1	1
3	256	21.5	26	33	38.7	47.2	58.1	1.3
3	257	20	24	26	27.5	28.3	39.8	1.3
3	258	28.5	35	44	53	59.2	100	2
plot eight								
3	259	28.5	32.5	33.5	39.1	50.6	63.1	1.4
3	260	16	20	20.5	21.8	23.6	37.8	0.4
3	261	35	41	43.3	49	67.2	87.8	1.8
3	262	24.5	30	33	37.1	43.6	50.2	1.2
3	263	12	16.5	26	32.1	43.2	62.9	1.4
3	264	19.5	25	28	33.2	49.1	61.9	1.2
3	265	40	46	49	59.1	88.3	110.8	2.1
3	266	29	33	34.5	37.1	64.6	88.7	1.9
3	267	31.5	36	38.5	44.3	68.3	91.8	1.5
3	268	37.5	43	47	64.1	93.4	110	2.2
3	269	26	33	34	42.1	58.9	74.2	1.3
3	270	26	32	36	39.5	40.5	49	0.5
3	271	37.5	43	46	47.8	63.1	75.5	1.4
3	272	26	30	36	39.2	49.6	56.2	1
3	273	25.5	30	35	41.1	57.3	73.1	1.5
3	274	30	35.5	40	51.5	70.2	81.1	2
3	275	20	25.5	27	28.1	28.6	30.1	0.4
3	276	30	36	38	40.2	63.1	77	1.4
3	277	22	27	28	30.3	33.1	42.9	0.5
3	278	25	31.5	32.5	41.1	41.9	52.8	1
3	279	9.5	11	12	18.9	20.4	24.1	0.3
3	280	24.5	27.5	30	32.1	32.8	36.1	0.5
3	281	22	27	28	30.2	39.3	48.1	1.1
3	282	21.5	27	28.5	31.2	38.6	43.2	1.1
3	283	35.5	42	43	45.1	52.4	56.3	1.2
3	284	36	42	43	45.2	52.2	64	1.4
plot one								
P. falcatus								
4	1	45	46.5	49	49.5	51	53.7	1.1
4	2	37	42	47.5	48	51.2	57.4	1.3
4	3	34.5	37.2	39	40	40.2	41.2	0.7
4	4	39	44.5	49.5	50.1	57.6	58.3	1.2
4	5	36	37	41.4	43.2	47.8	48.9	1
4	6	36	43.5	46	49.1	51.6	58.4	1
4	7	53	57.5	60	66.7	70.8	82.3	1.1
4	8	38.5	40	41.2	46.1	47.2	48.6	0.8
4	9	39	40.1	42	45.2	48.9	49.3	1.1
4	10	39.5	40.3	46	46.3	48.3	50.2	1
4	11	45	50.1	52.4	56.9	60.1	62.9	1.1
4	12	42	44.5	48.5	52.3	56.1	60	1.2
4	13	35	38.5	41.8	47	49.3	53.3	0.7
4	14	42	46.5	49.1	49.7	52.3	57.1	0.7
4	15	36	38	41.5	43.8	49.9	52.2	0.7
4	16	45.1	46.3	49.7	50.2	50.9	62.6	0.6
4	17	42	44.5	45.3	45.7	46.4	47.3	0.6
4	18	40	42.5	43.5	44.8	45.2	51.5	0.6
4	19	38	40	41.5	46.8	49.5	56.3	0.6
4	20	45.5	47	56.1	59.5	70.6	74.2	1.1
4	21	41	42.1	43	43.3	44.8	47.4	0.6
4	22	49.5	51.5	52	52.3	52.9	53.4	1
4	23	45.5	47	48.5	51.7	52.4	53.6	0.7
4	24	46	51	52	57.4	60.8	61.4	0.8
4	25	46	49.5	50.3	54.7	55.9	60.2	1

4	26	30	32.5	35.5	42.1	48.2	54.7	1
4	27	28	30	33.5	36.5	40.2	49.2	0.6
4	28	46	50.5	53.9	60	60.6	61.2	0.6
4	29	41.5	42	42.5	43.1	53.6	54	0.8
4	30	40.5	43	45.7	50.6	55.6	57.1	1.1
4	31	46.9	49.1	56	57.1	67.7	82.1	1.6
4	32	37.5	40	44.6	47.3	52.4	62.2	0.7
4	33	46	47	47.5	48.1	49.9	52.2	0.8
4	34	39	40	42.5	42.7	48.4	50.1	0.6
4	35	37	39	41.5	43.8	44.8	48	0.7
4	36	50	51.5	53	58.4	59.2	63.6	0.6
4	37	38.9	42.1	43	45.5	45.9	51.4	0.7
4	38	43.1	45.7	50.5	51.7	54.6	63.6	0.9
4	39	42	44.8	48	48.4	53.7	55.1	0.7
4	40	50.5	52	57.5	62.3	70.6	77.1	1.3
4	41	48.5	50.8	53.1	54.9	55.1	58.6	0.9
4	42	44.2	46	47.5	50.1	52.3	57.4	0.7
plot two								
4	43	43	43.8	47.1	48.4	48.8	53.4	0.7
4	44	48.9	53.5	54	60.1	60.9	65.2	0.9
4	45	42.5	46.1	48	48.2	49.4	58.2	0.8
4	46	35	38.5	40	42.1	43.1	50.8	0.7
4	47	46	48.5	52	53.2	61.9	62.7	1
4	48	42.5	48	48.5	54.5	56.6	63.2	0.9
4	49	34	35.5	36	39.7	40	43.3	0.5
4	50	32.1	34	35	37.6	37.8	44.4	0.7
4	51	26	27.5	29.9	35.3	38.7	48.3	0.5
4	52	36.2	38	42.4	44.6	46.2	53.4	0.6
4	53	39.5	44.5	46	46.1	46.5	52	0.6
4	54	44.1	45.5	46	46.7	47.7	56.2	0.7
4	55	39	40.2	41.5	41.7	43.6	52.1	0.7
4	56	39.5	42.8	44.9	47	48.2	52.6	0.9
4	57	47.5	51.2	53	53.5	54.1	64.7	0.8
4	58	58.9	61.5	66	69.6	70.2	72.9	1.2
4	59	30.1	34.2	35.8	39.1	42.6	59.2	1.3
4	60	40	42.3	44.9	48.9	53.4	62.2	0.9
4	61	34.1	35.8	40.1	43	46.4	51.3	0.8
4	62	38.5	45.1	49	52.6	55.3	63.3	0.9
4	63	36.5	38.3	41	41.6	44.6	45.4	1
4	64	29.5	34.9	40	41.1	41.9	52.2	0.8
4	65	38.7	41	42.5	43.4	49.2	53.2	1.1
4	66	35.9	40	43.5	45.7	51	62.3	1.1
4	67	35.3	37.6	38.5	40.6	41	55.2	0.7
4	68	37.2	40.7	41.5	43.1	44.7	47.3	0.6
4	69	37	38.1	41.6	44	44.7	46.3	0.7
4	70	53	56.5	57.1	57.7	58.2	61.2	0.6
4	71	32.5	36	39.5	40.3	51.4	56.7	0.7
4	72	34.7	38.1	40.5	41	41.9	43.4	0.5
4	73	42.6	46	52.9	60.1	66.4	80.6	1
4	74	28.5	30	31	33.6	38.4	45.6	0.9
4	75	26.5	28	34.3	39.7	42.6	56.4	0.8
4	76	55	56.5	63.5	64.1	67.5	73.4	1
4	77	35	37.6	40	40.3	41.8	50.6	0.8
4	78	36.5	38	38.5	38.9	40	41.3	0.7
4	79	36.5	40	41.5	41.8	43.3	56.7	0.8
4	80	38	39.5	42.1	43	43.2	52.2	0.6
4	81	41.5	44	47.5	54.1	54.8	59.3	0.9
4	82	31.1	33.2	34	34.5	35	40.8	0.5

4	83	34	34.7	35.3	35.9	36.1	38.3	0.4
4	84	41.5	45.1	49.3	52.1	53.4	56.6	1
4	85	22	26.5	28.5	31.2	32.2	40.8	0.6
4	86	40.5	41	42	42.7	43	47.5	0.8
4	87	32.5	35	36.5	36.7	37	40.6	0.8
4	88	34.8	38	42	42.5	43.8	50.7	0.9
4	89	35.1	36.8	38.1	39.3	40.6	47.4	0.7
4	90	40	42.5	43.5	47.6	50.9	52.6	1.2
4	91	52	54.5	56.5	57.8	60	64.7	0.9
4	92	32.2	33.4	35.5	36.8	38	43.4	0.8
4	93	46	47.5	51.5	52.7	62	73.6	1.3
4	94	40	42.1	43	47.8	51	58.2	0.7
4	95	43	46.5	50	54.8	57.4	65.2	0.6
4	96	44.5	48.5	49.5	50.4	54.5	58.4	0.9
4	97	40.5	43.9	45.5	46.7	47.3	52.4	0.5
4	98	44.5	48	50.1	51.2	54.8	56.2	0.8
4	99	32.9	37.1	38.7	39.3	39.7	43.2	0.5
4	100	46	47.5	48	51.1	53	57.4	0.9
4	101	46.5	50.1	51.5	53.2	56.8	68.3	1.1
4	102	48.5	53.4	55.9	60.3	62	70.4	0.9
4	103	54.3	59.1	62.8	63.7	67.2	74.3	1
4	104	37.4	40.2	46.5	48.3	49	54.8	0.9
4	105	23.5	27.4	30.1	31.5	32	39.6	0.4
plot three								
4	106	43.9	47.1	49.3	51.2	55.3	66.2	1.3
4	107	38.5	40	42.4	43.7	47.1	52.6	0.6
4	108	43.9	48.5	49.7	50.4	51.3	55.9	0.5
4	109	30	31.5	32.6	33.6	35.1	42.6	0.6
4	110	47.8	50.1	53.8	54.3	55.4	57.7	0.7
4	111	41	42.5	43.5	48.1	50.9	57.5	0.9
4	112	47.2	50.6	52.5	59.8	62.6	66.4	1
4	113	38.3	40.4	41.1	42	43.5	50.1	1
4	114	32.9	37.6	39	40.1	40.5	43.7	0.7
4	115	31.7	33	36.9	43.6	50.3	56.7	0.9
4	116	41.5	44.9	49.1	51	51.6	57.3	0.7
4	117	41.5	44.5	47	51.2	59.8	72.8	1.3
4	118	36	37.1	38	38.3	39.2	46.9	0.8
4	119	30.5	33.9	34.5	35.7	38.1	46.4	0.7
4	120	39.5	41.1	43.5	44.1	47.3	54.8	0.8
4	121	42	43.5	45	48.2	50.7	53.9	1
4	122	50.5	56	60.1	63.8	67.6	77.2	1.1
4	123	39	43.2	45	47.6	48.2	53.6	0.7
4	124	48.5	53.3	56	58.1	61.4	64.8	1.2
4	125	41.5	45	46.9	51.5	54.2	56.7	1
4	126	42.5	45.5	46	49.5	52.5	59.6	0.9
4	127	36.5	40.3	43	44.1	48.6	49.9	0.9
4	128	43.5	48	51	56.8	59.2	69.3	1.2
4	129	35	35.5	38.1	43.2	45.8	57.6	1
4	130	43	47.5	48.6	49.2	55.3	57.3	0.9
4	131	35	39	41.7	46.1	47.4	56.8	1.1
4	132	40	43	44.3	47.2	48.2	54.4	0.7
4	133	42	43	43.5	45.3	51.6	56.2	1.1
4	134	30	31.5	35.8	42.1	46.9	56.8	0.8
4	135	43	47.1	47.5	50.6	56.5	57.8	1.1
4	136	48.5	55	60	61.2	75.4	78.8	1.2
4	137	32.7	35	37.3	38.8	43.6	48.9	0.7
4	138	42.5	45	48.3	49.1	52.2	65.2	1
4	139	46.7	49	50.8	57.5	61.5	68.8	1

4	140	30.2	34.1	35.2	37.9	40.1	48.9	0.7
4	141	42.5	45	45.9	46.1	52.3	58.8	0.8
plot four								
4	142	34	36.5	37	38.2	39.1	44.4	1
4	143	35	37.5	40.4	42.8	44.9	52.8	0.8
4	144	37.7	40.5	43.9	47.6	50.6	57.4	1.1
4	145	17.5	20	21.5	22.3	38.2	55.3	1
4	146	21.4	25	28	32.1	34.6	45.6	0.9
4	147	39.5	43.5	47	48.1	51.4	68.6	1.2
4	148	34	37.5	39	43.6	44.3	51.6	0.8
4	149	17	20.8	25	26.2	29.1	37.4	0.6
4	150	26	27.5	28	30.1	31.1	35.2	0.6
4	151	42.6	44	45.5	46	52.9	54.2	0.9
4	152	42.5	43.5	44	48.1	51.3	67.4	1.1
4	153	44	47.6	50	51.2	56.3	60.2	0.9
4	154	40.5	45.1	49.2	50	55.4	62.4	1.1
4	155	48.3	49.6	51	54.5	63.5	69.3	0.9
4	156	38	39.6	40.5	41.3	42	47.3	0.5
4	157	26.1	29.3	30	31.3	31.5	43.6	0.5
4	158	34.2	38.4	41.5	44.5	46.4	52.8	1
4	159	38.5	41.3	42.1	42.7	43.1	47.8	0.7
4	160	53.1	57.2	58	58.9	60.1	66.3	0.9
4	161	47.5	52	52.5	53.9	55.2	59.6	1
4	162	42.5	48.3	49.5	50.7	55.9	56.7	1.1
4	163	28.1	31.6	35	36.2	42.9	50.8	0.9
4	164	39.3	41.2	42	42.5	46.5	51.3	0.9
4	165	38.5	42	44.5	45.6	46.2	51.6	1.1
4	166	41.7	44.3	46.1	46.9	48.8	56.3	0.6
4	167	27.5	30.1	32.6	35.7	38.3	50.6	1
4	168	46.4	49	51.2	52.3	57.4	64.3	1.1
4	169	36.3	38.6	40.9	45.8	51.2	60.8	1.2
4	170	29.3	32.9	35.6	41.5	44.2	50.4	0.8
plot five								
4	171	38.1	42.1	46.7	47.5	54.2	58.6	0.8
4	172	50.2	52.3	53.9	56	56.6	61.4	1
4	173	44	45.5	46	46.3	47.1	54.2	0.6
4	174	28.3	31.4	33	35.6	40.3	51.4	0.5
4	175	28.2	33.3	37	38.7	46.3	55.3	0.8
4	176	36.5	38.4	39.5	41.3	43.2	48.6	1.1
4	177	30.3	34.5	35.8	36.9	39.2	51.4	0.6
4	178	44.9	49.7	50.1	51	52.1	57.2	0.8
4	179	58.4	64.3	65.2	67.1	69.3	77.2	1.3
4	180	26.3	29.5	31	34.6	40.2	50.8	0.6
4	181	42.1	44	44.6	45.1	45.9	48.2	0.8
4	182	32.5	36	37.4	38.6	38.9	46.2	0.7
4	183	45	48.7	51.3	56.1	58.5	70.5	1.1
4	184	27.1	28.3	29	30.1	30.7	32.2	0.2
4	185	30.3	34.1	34.8	35.1	35.7	45.3	0.6
4	186	43.6	45.5	47	48.2	48.5	50.1	1.1
4	187	39.2	40.5	41.6	42.1	46.1	47.6	0.9
4	188	36.5	40	40.5	41.7	42.3	52.7	1
4	189	39.5	41.6	42.5	43.1	44.3	50.2	0.8
4	190	33.4	36.2	37.5	39.8	41.2	44.6	0.7
4	191	41.6	44.3	45.6	46.1	48.8	59.1	1
4	192	41.4	45.5	46	48.8	52.1	58.9	1.2
plot six								
	193	46	50.5	51.5	57.9	62.2	75.6	1.1
4	194	45.5	48	49	52.6	56.1	58.4	1.1

4	195	32.1	34	36.4	39.8	43.1	45.7	1
4	196	45.5	48	49.3	50.2	50.5	56.3	1.1
4	197	43.5	46.5	47.3	48.2	49.2	55.8	1.2
4	198	43.1	44	47.4	48.1	48.3	54.6	0.8
4	199	36	38.3	40	41.5	42.8	50.4	0.8
4	200	38	42.5	44.6	49.6	49.9	56.4	0.7
4	201	38.5	41.2	42.5	43.1	44.6	45.8	0.7
4	202	47.5	49.1	50.1	50.5	53.7	55.2	0.6
4	203	25.5	26.1	27	27.5	27.7	28.3	0.5
4	204	26.3	30.8	35	37.4	44.3	51.3	0.6
4	205	33.5	38.5	39.4	40.6	41.1	46.4	0.5
4	206	38.2	41.1	41.5	42	42.6	46.2	0.9
4	207	36.3	38	42.8	43.5	44.2	53.6	0.7
4	208	47.9	52.5	55.1	56.5	58.1	60.6	1.1
4	209	41.2	42.5	43	43.6	46.8	49.3	0.8
4	210	30	32.5	33.8	34.1	34.8	38.4	0.6
4	211	32	35.5	36.4	37.5	39.2	45.3	0.6
4	212	36.5	38.5	41	43.8	45.6	51.8	1.1
4	213	29.2	31.8	32.5	36.9	38.4	45.6	0.8
4	214	36.2	36.6	37.1	37.5	43.8	47.6	0.9
4	215	33.4	36	37.4	38.1	39.1	46.2	0.8
4	216	30.1	31.5	33	34.2	43.7	51.9	0.9
4	217	20.9	24.8	27.6	30	33.4	46.4	0.7
4	218	28.9	34.1	35.3	38.5	49.3	59.6	1
4	219	33.1	34.5	36.5	41.1	44.3	52.4	1.2
4	220	41	45.3	49.8	51.6	57.6	64.6	1.1
4	221	26.5	30.3	31.5	32.6	34.3	35.4	0.3
plot seven								
4	222	44	45.5	46.3	48.6	49.9	54.4	1
4	223	41.2	45.3	46.4	47.3	54.3	61.2	1.1
4	224	29.5	36.5	37.5	40.1	42.6	54.6	0.9
4	225	36.9	42.1	43.5	45.3	48.7	50.8	0.8
4	226	29.5	33.4	34.5	35.2	36.5	48.3	0.6
4	227	34.1	36.7	38	41.2	42.7	47.6	1
4	228	27.5	31.8	32.6	33.2	33.5	43.2	0.6
4	229	36.3	37.5	38	39.9	41.2	46.4	0.7
4	230	33.5	35.5	36.1	36.7	37.3	42.4	0.6
4	231	33.5	36.5	38.1	38.6	38.8	44.2	0.5
4	232	37.2	41.1	41.8	42.3	42.8	48.4	0.6
4	233	39.8	42.2	44.5	45.3	56.9	62.8	1.1
4	234	33.3	34.8	35.5	36.7	45.8	68.9	0.7
4	235	35.9	40.8	45.1	46	48.4	52.6	0.9
4	236	26.1	28.2	34.5	35.8	37.1	43.4	0.5
4	237	33.5	39.2	45.2	46.5	48.6	52.6	1.1
4	238	40.2	44	46.9	48.6	50.2	62.4	1.1
4	239	35.5	42.5	47	52.1	57.4	63.6	1.2
4	240	21.5	24.5	25	26.3	28.7	37.4	0.7
4	241	44.5	49.5	52	53.9	58.2	63.2	1
4	242	34.5	36.4	37.8	38.2	41.4	48.2	0.5
4	243	44.8	46.8	50	52.5	56.2	59.2	1.2
4	244	53.8	57.5	60	61.6	68.2	76.4	1.1
4	245	38.5	42.1	45.5	54.3	61.3	73.4	1.3
4	246	21.5	25.9	33.5	34.7	40.3	54.8	0.6
4	247	26.5	30	32	34.3	46.8	60.8	1
4	248	34.2	38	39.3	40.2	40.5	48.6	0.7
plot eight								
4	249	37.5	43.1	50.9	54.3	60.2	70.5	1
4	250	21	23.5	32	35.3	36.8	43.6	0.6

4	251	60.5	65.3	67.5	70.1	77.6	89.6	1.6
4	252	48.2	50.1	56.5	57	66.2	72.7	1.1
4	253	51.6	56.5	60.3	66.4	75.3	86.7	1.5
4	254	34	36.5	37	37.6	49.3	49.4	0.7
4	255	36	40.4	41.6	45.2	47.6	58.6	1

Appendix **2.** Mean relative growth rate for height (RGRH) of the four species seedlings.

Species	RGRH1 (45 days)	RGRH2 (90 days)	RGRH3 (135 days)	RGRH4 (180 days)	RGRH5 (225 days)
C. africana	2.48	2.17	1.86	2.44	3.73
C. macrostachyus	2.74	1.74	2.41	3.21	3.59
M. ferruginea	3.87	2.34	2.85	6.03	4.69
P. falcatus	1.73	1.23	1.08	1.59	2.83

Appendix **3.** General condition (status) of the four species seedlings under the study period (225 days).

Species	N (at the beginning)	wilted	browsed	Tip - dried	broken
C. africana	88	_	_	11	1
C. macrostachyus	348	2	1	16	1
M. ferruginea	303	2	16	_	1
P. falcatus	256	_	1	_	_

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