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Selection of Trees and Shrubs Species for Frost Prone and Degraded Highland of Legambo Woreda, South Wollo, Amahra Region, Ethiopia

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ABSTRACT

High altitude a forestation in South Wollo has been difficult due to lack of adaptable tree species and partly due to stressful environmental conditions. This study is intended to select the best-performing tree species for frost prone highlands of south Wollo. *Erica arborea, Hagenia abyssinica, Eucalyptus globulus, Hypericum revolutum, Populus sp*ecies, *Chamaecytisus palmensis, and Juniperus procera* were evaluated in a randomized complete block design with three replications. Five seedlings from each species were planted with one-meter spacing in a plot. Spacing between plots and blocks was 1.5 m and 2 m, respectively. Data collected include plant height, root collar diameter, and number of branches, which were measured at an interval of six-months period, and for three years. One-way Analysis of Variance results showed the presence of significant variation in measured parameters. *Eucalyptus globulus* has demonstrated the highest result in seedling height and root collar diameter at the end of three years. *Populus species, Chamaecytisus palmensis,* and *Juniperus procera* showed the second, third, and the fourth better growth performance.

Keywords: Environmental Stress, Frost-prone, Growth performance, Shrubs.

INTRODUCTION

Mountains are important biogeographical features as places for home for indigenous people and as sources of freshwater for humanities (Messerli & Ives, 1997). Most communities living in the mountains are rich in culture, history and indigenous knowledge. Moreover, 60 - 90% of the freshwater in the world comes from mountains (Beniston & Stoffel, 2014), and a similar amount of people get energy from the electric power generated by water from the mountains. Mountains are also the sponges to absorb water which will be stored as underground aquifer which will be later used as drinking and irrigation (Messerli et al., 2004). Mountain biogeography is similar to island biogeography; hence a high degree of endemism in fauna and flora is expected (Puff & Nemomissa, 2001).

In contrast to the importance of mountains for the world, people living in mountain areas are very poor and the environment is highly liable for degradation due to soil erosion by water and wind (Zeleke & Hurni, 2001). Efforts to rehabilitate mountain areas are not successful in many places. High altitude a forestation is extremely difficult due to lack of alternative species, environmental stresses due to frost and unfavorable edaphic conditions (Körner, 2007; Ko, 1998) including frost heaving.

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Areas subject to frost heaving have below-freezing air temperatures, high soil moisture and frost susceptible soils (Goulet, 1995). In many parts of the world where these conditions are found, frost heaving can be a leading cause of tree seedlings mortality. Even though this is a well-known problem, it has been hard to qualify and quantify. Foresters and agronomists have been observing and describing the process of frost heaving of plants (Goulet, 1995; Sahlén & Goulet, 2002).

The nursery and early establishment phases of forest products are generally recognized as being the most vulnerable to frost damage. Even if frost heaving of forest tree seedlings is difficult to control, it could be reduced by determining the susceptibility of soils to frost action and then taking appropriate ameliorative measures such as fertilizing, sowing or planting at the proper time, planting big seedlings and modifying the soil environment by draining, shading and the use of mulches (Chantal et al., 2006). Site preparation should be restricted to the minimum necessary for control of competing vegetation.

Freezing stress is one of the most important limiting factors determining the ecological distribution and production of tree species. Assessment of frost risk is, therefore, critical for forestry, fruit production, and horticulture. Frost's risk is substantial when hazard (i.e. exposure to damaging freezing temperatures) intersects with vulnerability (i.e. frost sensitivity). Frost risk (probability of frost damage) increases when hazard (probability of a given freezing temperature) coincides with vulnerability (frost sensitivity) (Walter et al., 2013).

Tree frost resistance involves two main strategies: avoidance and tolerance (Taschler et al., 2004). A stress avoidance strategy was exhibited by some species. The spatial and temporal distribution of sensitive organs and meristem protects from cold temperatures. Tolerance to Freezing: damage to plant tissues depends on the quantity, location, and rate of formation. However, plants can partially control ice formation, lessening frost risk. Ice formation could be avoided by the production of anti-nucleates such as anti-freeze proteins (Levit, 1985). This study was intended to select the best frost resistance trees species in the study area

Globally little success has been documented in investigating fast-growing tree species suitable for high altitude a forestation (Mather, 1971; Pears, 1968). According to the same authors, natural altitudinal limits, harsh environmental conditions, mainly strong wind, and unfavorable soil conditions limit the growth of natural plants. There are also limited silvicultural studies which can assist plants to thrive in these harsh environmental conditions. Economic yields per hectare in forestry are low compared with agriculture and trees must be adapted to a far wider range of conditions. However, the area of potential production for forestry is often large and even small improvements in establishment or productivity may be very significant at the national level both in terms of social benefits and in terms of land values and the production of raw material for industry. For the variety of species that we may be required to consider in any one national or regional tree planting program, an array of methods for handling the various program phases would be desirable. Therefore, appropriate gene management methods could be applied to each species or population.

An optimum program requires information on the biology of the species in its native habitat as outlined above but also requires information on the habitats in which it is to be used. If a species is to be used within its area of adaptation, then some degree of trust can be placed on how well individuals or stands perform in their native habitat. If a species is to be used outside its native habitat, however, a different and wider range of adaptations is required of the species than it has previously produced and a different and wider range of biotic agents may be present which can adapt to it than previous evolution has tested.

In increasing tree improvement, selection starts at the species/provenance/population level. Most species (particularly those in the tropics); show patterns of variation over their natural range which are indicators of vast genetic variation which can be released by breeders (Namkoong et al., 1980).

MATERIALS AND METHODS

Study area:

The research was carried out in Legambo woreda (Fig. 1). It is one of the woredas in the Amhara Region of Ethiopia. Legambo is bordered on the south by Legahida and Kelala, on the southwest by Wegde, on the west by Borena, on the northwest by Sayint, on the north by Tenta, on the northeast by Dessie Zuria, and on the southeast by Were Ilu. Elevations in this woreda range from 1500 to 3700 meters; the highest point in this woreda, as well as the Debub Wollo Zone, is Mount Amba Ferit, which lies on the border with Sayint (EMA, 1988).

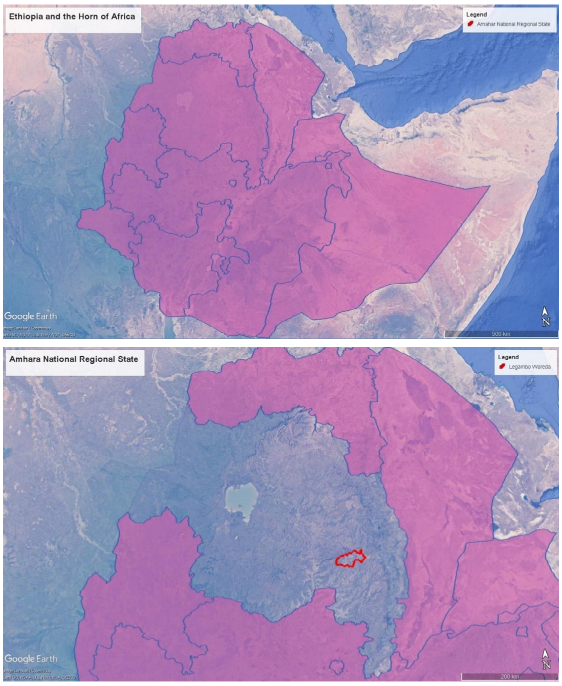

Fig. 1: Map of Ethiopia, Amhara National Regional State and Legambo district is bounded in red, derived from Google Earth

Climate:

Assessments The study area is characterized by both wet and dry seasons. The distribution of rainfall mostly occurs from June to September (big rain season), locally known as “Kiremt”, and February to May is the small rain season, which is locally known as “Belg”. The small rainy season is erratic and highly variable. There is a long dry period from the end of October to February, and a short dry spell in June. As presented in Fig. 2, the metrological data obtained from Woreilu Metrological Stations, near 15 km from the study area, during the year 1990 to 2007, the mean annual temperature and mean annual rainfall 23-30 ºC and 1130 mm, respectively.

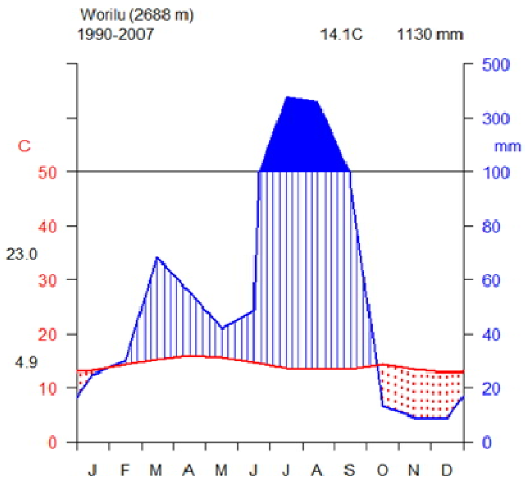

Fig. 2: Walter-Leith diagram showing the monthly rainfall distribution in the area from the year 1990 to 2007 (Data source:NMSA, 2015)

Planting materials:

Four exotic and four indigenous tree species were evaluated for their adaptation of the environmental condition of the area. The following species were selected for this experiment: *Morus alba*, *Erica arborea*, *Hagenia abyssinica*, *Eucalyptus globulus*, *Hypericum revolutum*, *Juniperus procera*, *Populus alba*, and *Chamaecytisus palmensis*. The species were selected based on species preferences, availability of germplasm and capabilities of the area. Information concerning planting materials is summarized (Table 1). Seedlings of the selected trees species had been raised in the government nursery near to the experimental site, the species were produced in the nursery with the recommended seedling management techniques.

Table 1: Information concerning planting materials

Species	Source	Remark
Morus alba	FRC	Exotic
Erica arborea	Borna NP	Indigenous
Hagenia abyssinica	Borna NP	Indigenous
Eucalyptus globulus	FRC	Exotic
Juniperu sprocera	FRC	Indigenous
Populus alba	FRC	Exotic
Chamaecytisus palmensis	FRC	Exotic
Hypericum revolutum	Borna NP	Indigenous

Where, Eu = Eucalyptus globulus, A = Populus Alba, B= C. palmensis and C = Juniperus procera, FRC= Forestry research center

Experimental design:

The experimental design was arranged in a randomized complete block design (RCBD) with three replications. Five seedlings from each species were planted per plot. Spacing between plants, plots and blocks were 1.0 m, 1.5 m and 2 m, respectively. After the production of the required number and quality of the seedlings, the experiment was implemented.

Data analysis:

The raw data were organized and analyzed using spreadsheet software. SPSS was used for ANOVA. Mean separation test, mainly Least Significance Difference (LSD) was used to evaluate if there are significant differences in means of selected performance evaluation parameters. These techniques have been indicated by Hollander and Wolfe (1999), Fligner (1984) and Levitt (1985).

RESULTS

Among the planted tree species, only four tree species namely *Eucalyptus globulus*, *Populus alba*, *Chamaecytisus palmensis*, and *Juniperus procera* showed better performance in terms of plant height, root collar diameter, and number of branches. Thus, in the year 2010, the total height attained by *E. globulus* was 3.09 m. This was followed by *Populus species* (2.44m), *C. palmensis* (2.20 m) and *J. procera* (1.5 m) (Fig. 3).

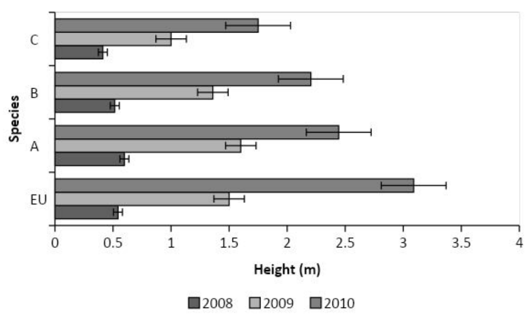

Fig. 3: Summary of the performance of tree species in frost prone area of south Wollo. Where, Eu = *Eucalyptus globulus*, A = *Populus Alba*, B= *Chamaecytisus palmensis* and C= *Juniperus procera*

Similarly, the highest growth in root collar diameter (RCD) was recorded in *E. globulus* (0.16 cm), whereas *Populus sp*, *C. palmensis*, and *J. procera* demonstrated comparable results (0.06 cm) (Fig. 4).

In terms of number branches, the highest value was recorded on *E. globulus*, followed by *J. procera* and *C. palmensis*. The number of branches for *E. globulus* was 30, and for *J. procera* was 23, and the

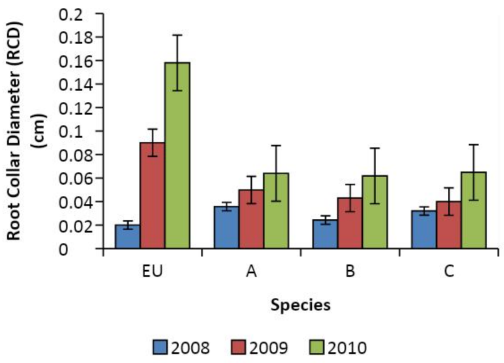

Fig.4: Root collar diameter of the tree species along the experimental periods. Where: Eu = *Eucalyptus globulus*, A = *Populus alba*, B= Chamaecytisus *palmensis* and C= *Juniperus procera*).

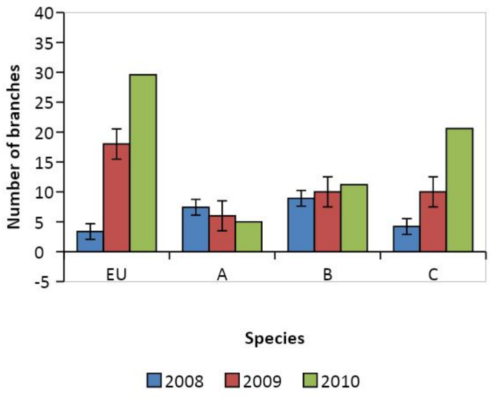

Fig. 5: Number of branch of the tree species along the experimental periods. Where, Eu = *Eucalyptus globulus*, A = *Populus alba*, B= Chamaecytisus *palmensis* and C= *Juniperus procera*).

value for *C. palmensis* has been 11, and *Poplus* showed lower branches (10) (Fig. 5).

There was a significance differences among tree and shrub species in terms of plant height ($P<0.05$). Similarly, there was a significant difference in root collar diameter ($P=0.05$) and the number of branches per tree.

Although there were statistically significant differences in RCD and the number of branches among the trees compared, there were non-significant differences between some of the tree species. For instance, there was a non-significant difference in RCD between *Populus sp*., *C. palmensis* and *J. procera*. Similarly, there was non-significant difference between *Populus sp*., *C. palmensis* and *J. procera* in the number of branches.

DISCUSSION

Mountains are important biophysical and socio-ecological features. Biophysically, mountains are sources of fresh water, energy, and tourism. Socio-ecologically, they are home for poor peoples of the world, they are degraded whereby the extreme climatic conditions of the high altitude shaped the social and ecologic contexts. Furthermore, fragile mountain ecosystems are further degraded with increasing population and the accompanying insatiable demand for fuel, food, and fodder.

The Ethiopian highlands are the water tower of Africa. They need to be sustainably managed to ensure their ecological and economic contributions. Tree-based natural resource management systems are nature-based solutions with a win-win situation for humans and the natural environment (Vanclay et al., 2003). However, this approach has been constrained in frost-prone highlands of South Wollo due to the absence of alternative tree species that can persist and grow in the area.

The performance of a given species at a given site is affected by genetics and environment. The first step in selecting tree species appropriate for a given site starts with selecting the appropriate species, once the appropriate species is obtained, the next step will be selecting best-performing provenances, families, and varieties in the species (Graudal & Kjær, 2000). This study has screened and recorded the performance of trees species in the frost-prone areas of Legambo high lands. Plant height, root collar diameter, and branch number are important indicators first to evaluate the survival and growth of the species in the area. Second, the potential of the species for its biomass production, and third suitability of the species for fuel wood, fodder, or the restoration of degraded ecosystems.

Among compared tree species, the growth rate at field condition was found to be lower for *Morus alba*, *Erica arborea*, *Hypericum revolutum* and *Hagenia abyssinica*. However, *E. globulus* has attained the highest height and the largest root collar diameter. *Populus sp*., *C. palmensis*, and *J. procera* are the second, third and the fourth better-performing species in the area. *E. globulus* is important tree species as a source of fuel wood and its potential as a source of income. It can grow fast and resist animal browse. In many areas, it has been reported to be a source of major income for poor high landers (Jagger & Pender, 2003). The ecological role of E. globulus in some areas of South Wollo has been also reported (Abiyu et al., 2011).

Regarding the selection of the species for a forestation or reforestation purposes, research on ecological and sociological effects are needed to forward the recommendations. Future studies should further evaluate the presence of differences in provenances among the best performing species. The presence of variation among provenances, populations, and families in the growth performance of tree species has been observed in many tree species (Graudal & Kjaer, 2000). Future studies should also aim at investigating the relation between plantation of fast-growing tree species, livestock production, and groundwater recharge capacity of mountains.

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