Survival and Growth Response of Four Agroforestry Species to Post Planting Management Regimes

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Abstract

Post planting seedling management activities are important factors that determinegrowth and survivalof tree species. A study was conducted to evaluate the effect of management regimes on growth and survival of*Cordia africana, Croton macrostachyus, Vachelliaabyssinica*, and *Grevillea robusta*tree species. The management regimes (treatments)were with and without application of fertilizer, irrigation and weeding. Management regimeswere arranged in split-split-split plot design replicated three times with tree species as main plot factor and other treatments randomized totheir assigned sub plots. Plant height, root collar diameter and survivaldata were collectedfor statistical analysis. The nonparametrictestKaplan-Meierwas used to estimatesurvival probabilities. Besides, multivariate analysis and Tukey HSD for post hoc testswereemployed for assessing management effects on growth parameters of the tree species. Accordingly, time and management regimes significantly affected growth and survival of tree species. Seedlings with one and four months after planting had better survival and growth rates than twenty months after planting. Apart from main effects fertilizer and weeding, management regimes revealed no interaction effects.*Vachelliaabyssinica* and *Cordia africana*hadhigher survival rates, while*Vachelliaabyssinica* revealed least in growth rate. Height and diameter of *Cordia africana* and *Croton macrostachyus*had significant and strong correlations with fertilizerand so does weeding with*Grevillea robusta*.Generally, management regimes improved growth and survival of the tree species. However, effect of irrigation and fertilizer rates on growth and survival of agroforestry tree speciesrequires further systematic study for packaging management recommendation.

Introduction

It has been decades since commencement of plantation in the drylands(Lemenih and Kassa, 2014). However, growth and survival of tree species had not been satisfactory mainly attributed to poor species-site matching (Birhane et.al., 2020). Besides, successful establishment and growth of seedlingsis also a function of multiple pre and post planting management regimes.Sorecha, (2017)reported lack of seedlings aftercare reduced survival rate and resistance to harsh environments.The right post planting managements are required to enhance the growth and survival of tree seedlings (Dereroet al., 2021).Farmersuse different management regimes (fertilizer, weeding, fencing, hoeing, and irrigation) for improving growth and survival rate of tree species(Boreuxet.al., 2016;Wariyo and Negewo, 2023). Similarly, Amha et.al., (2020), indicated that growth and survival of tree species can be improved by using different management regimes like inorganic, organic manures and watering.

Soil moisture is essential for successful seedling establishment and growth (Bahramovet.al., 2020)and nutrient uptake(Lu et al., 2019).Effect of soil moisture content on survival, growth and physiology of tree seedlings can be changed under different nitrogen fertilizer treatments (Aliarab et.al., 2020).Under drought conditions, soil water content decreases extremely, and mobility of nitrogen restricted severely(Byambadorj et al., 2020).Then, plant nitrogen uptake decreases and nitrogen deficiency occurs in water stressed plants(Aliarab *et.al.*,2020).Thus, fertilizer is effective for plant growth and development with the availability of soil moisture (Shehab and Guo, 2019).

Weed competition is also a major obstacle for achievingsuccessful establishment and growth of seedlings(Bonin et.al., 2018). Weeds, left uncontrolled, might turn into severe infestations, and impede seedlings establishment. Interference from weeds can range from significant suppression of growth to widespread mortality of seedlingsup to68% (Gazoulis et al., 2021).andweeds can competefor light, moisture, and nutrientswhich thisincrease susceptibility to attack from pests and diseases(Davis and Pinto, 2021).Removal of weeds through frequent hoeing is thus, essential for good early growth of seedlings (Davis and Pinto, 2021) and improving seedlings access to water and nutrients (Gazoulis et al., 2021).

Fertilizer improves growth and survival rate of indigenous and exotic tree species (Amha et.al., 2020;Ribamar et al., 2022; Agathokleous et.al., 2023).Moreover, survival and growth performance of seedlings is closely associated with seedlings nutrient reserves at the time of out planting(Oliet et al., 2017; Villar-salvador et.al., 2015).Most often, soils lack nitrogen, phosphorus and potassiumelements in their mobile forms(Bahramovet.al., 2020),and hence,reserves in the soil must be replenished.Nitrogen is the most important nutrient that tree seedlings require in high amount and its availability make great variations in seedlings growth and performance (Villar-salvador et.al., 2015). Phosphorus starvation disrupts protein metabolism, negatively affects the development of roots, impairs the process of photosynthesis, growth of shoots and leaves(Bahramov*et.al*.,2020).The right application of fertilizers should regulate soil acidity, increase vital soil microorganisms activity, create an optimal ratio of nutrient thereby contribute to better root activity and optimal development of the aboveground part (Uscola et al., 2015).

Growth performance of indigenous tree species is poor and as a result, farmersused to plant fast growing exotic trees like Eucalyptus species. The overallsurvival rate of seedlings in Western Oromia in Ethiopia varies between45.6 (± 32.6) % at 6 months and 33.6 (± 25.5) % at 14 months(Derero et al., 2021).The probability of overall seedlings survival before reaching one year old was 34% indicating much remains to be done in improving survival (Dereroet al., 2021).The most important factors attributed to poor survival and growth of seedlings were low soil fertility, poor seedling quality, water stress, insects, weeds, species-specific factors and free grazing (Mganga et al., 2018and Talema et al., 2019).Farmers demand to improve the growth and survival of the most preferred multipurpose tree species in the areanamely, *G. robusta*,*C. africana*,*C. macrostachyus*and *V. abyssinica*(Derero et al., 2021;Mezgebu, 2023). Moreover, farmers in south west Ethiopiapreferred both indigenous and exotic tree species such as *C. africana*, *C. macrostachyus*and *G. robusta* tree species for coffee shade (Wariyo and Negewo, 2023) and *V. abyssini*ca for fuel wood.Thus, considering the farmers preference, seedlings of the tree species were planted at Bako agricultural research center and monitored for twenty months at field conditions. The objectives of the study were (1)evaluatingsurvival rate, (2),growth performance and (3)relative growth rate (RGR)of the tree species subjected to post planting management regimes (fertilizer, weeding and irrigation) under the sub-humid agro ecological conditions of West Oromia, Ethiopia.

Materials and Methods

Study area description

The trial was conducted at Bako Agricultural Research Center (BARC) which is located at 258 km west of the capital, Addis Ababa, western Ethiopia. The study site is located at 9°11’ N latitude and 37°04’ E longitude at an altitude of 1650 meter above sea level.Agro-ecologically, BARC is classified as tepid to coolsub humid areas(Abera et al., 2009). The Bako Tibet district is divided into three agro-ecological zones involving lowland (51%), midland (37%), and highland (12%) (Degef et.al., 2023).The dominant soil type of the area is Nitisol, which is reddish brown in color and loamy in texture with pH of surface (5.4 to 6) and subsurface (5.2 to 6.6) (Hazelton & Murphy, 2016).This acidic property of the soil increases the solubility of Al oxides and hydroxides which results to the low availability and deficiency of phosphorus (P) in the study area (Dinssa and Elias, 2021).The area has mixed crop-livestock farming systemwith maize, tef, andsorghum major crops, and cattle, small ruminants and poultryas important livestock resources(Tulu et al., 2021; Dabesa and Tana, 2021). According to BWAO, (2020) the natural vegetation is a dry Afromontane and grassland complex type, and *C. africana* is the priority tree species in the area.The district land use types showed 70.2% arable land, 18.5% grazing land, 9.4% forest land and 1.9% others (Hussen and Geleta, 2021).

The area receives an annual rainfall of 1,605 mm mainly from May to September(Keba *et.al.*,2022). The minimum and maximum air temperatures were 13.4 and 28.4°C, respectively and average monthly potential evapotranspiration of the district was 47 mm estimated from two consecutive years (Daba and Tadese, 2018). During the study time, the minimum, and maximum temperature were 13°C and 28°C, respectivelywhich was similar with its previous years. The highest temperature in the area lays between the months of January and May (Fig. 1). The rainfall data obtained from the nearest weather station (BARC) reveals that the rainy season covers from May to September (Fig. 1) with 1401.5 mm of annual rainfall.

Experimental designand treatments

Four tree species namely*C. africana, C. macrostachyus, G. robusta and V. abyssinica*were selected and subjected to treatments (management regimes). The experimental design was a split-split-split plot design with tree species as main plot factors (Fig. 2) and fertilizer, irrigationand weedingas sub plot factors each with two levels (with and without management regimes). The main plot factors (tree species) were randomized first, and the sub plot factors similarly randomized with in the main plots.Treatments were replicated three times in randomized complete blocks. Each block containssixteen sub and thirty-two sub-sub plots with four seedlings of the same tree species per sub plot. Half of the seedlings in the sub plot were subjected to management regimes and the remaining kept as control. Hence, sixty-fourseedlings per block, totaled 192 seedlings of the tree species were subjected to the different management regimes. The spacing between plants and plots were one meter while twometers between blocks. Plot size was two by two meter and hence, the total dimension of the experiment was twenty by forty meters. Pits were prepared two weeks ahead of plantation for moisture retention and the site was fenced for protecting from animal and human interference. The treatments (factors) were weeding, fertilizer application and irrigation. The treatment combinations were the following;

T_1). Fertilizer T_2). Irrigation

T_3).Without watering, fertilizing and weeding (control)

T_4). Weeding T_5). With fertilizer, weeding and watering

T_6). Fertilizer and watering T_7). Fertilizer and weeding

T_8). Weeding and watering

The main plot factors (thespecies) indicated by different colors below contains four sub plots and eight sub-sub plots (Fig. 2). The shaded part in plot one (P_1) is the sub plot and the broken lines inside that plot were used to show the sub-sub plots.

Each blockwas labelled with laminated field lay outfor ease of data collection and follow up. The amount of fertilizer applied to each seedlingsthat receive fertilizer as treatment were 138 gram of Phosphorus (P) and 123 gram of Nitrogen (N). The fertilizers Nitrogen (N) and Phosphorus (P) were appliedmanually with banding method of application. Phosphorus (P) and Nitrogen (N) were applied one month and seven months after planting respectively. Moreover, the amount of water applied to each seedling that receive this treatment was 15 liter/plant/week. A graduated cylinder was used to manually measure and apply the amount of water to each seedling assigned to receive this treatment.The seedlings were irrigated weeklyduring the dry season (October to May). No water was given when it rained on the scheduled irrigation day.Daba and Tadese, (2018)used similar amount of water (14 litter/plant/week) in the same area (Bako district) and obtained significant results on growth performance of tree species. Moreover, weed had been controlled throughout theduration of the study (twenty months)for some of the seedlings (according to treatments) while others remain not weeded. Hand weeding was performed regularly to preventthe growth of weeds on the surface.

Data collection and measurements

Survival rate, root collar diameter and plant height of eachseedlingwas collectedat one, four, seven, eleven, fifteen, and twenty months after planting.Root collar diameter and plant heightwere measured using Vernier caliper andtape meterrespectively. Dead and survived seedlings of each species and treatments were counted and recorded for calculating survival percentages. Moreover, rainfall and temperature data were collected from Bako agricultural research center.

Data analysis

The non parametric Kaplan-Meier (Bland and Altman, 1998)using IBM SPSS version 20 was used to estimatesurvival functions based on time to the occurrence of the event. The Kaplan-Meier curve was used to estimate the survival function and probabilities. Multivariate analysis of variance was employed to evaluate treatment effectson plant height and root collar diameter of the species and Tukey HSD mean separationwas used for multiple comparisons.The survival rate, plant height and root collar diameter collected after twenty months of plantation were considered as dependent variables for analysis. The factors were fertilizer, irrigation, weeding and the tree species. As no measurements were taken at planting (initial), the one-month data of survival rate, root collar diameter and plant height were considered as covariate for analysis of the twenty months corresponding data. Normality (with Shapiro-Wilk test, $p > 0.05$), equality of variance (Levene's test) and data independencewere assessed to decide which test (parametric or non-parametric) to use. Accordingly, plant height and root collar diameter dataof the tree species were not normally distributed. Hence, Ln and square root transformations were used for analysis of plant height and root collar diameter respectively. Moreover, relative growth rate (RGR) for plant height and root collar diameter were calculated according toHoffmann and Poorter, (2002)equation.

$$RGR = \frac{\mathrm{lnx2} - \mathrm{lnx1}}{t2 - t1} \text{ day}^{-1}$$

Where: RGR is the relative growth rate, x_1 and x_2 arethe initial and final values of the measured variables at times t_1 (initial) and t_2 (final) respectively and $\ln x_2$ and $\ln x_1$ are the means of the natural logarithm-transformed measured values at times t_1 and t_2.

Result

Survival rate of seedlings

Time and management regimes ($P < 0.01$) had significant effect on survival rate of the study tree species. In the first month after planting, survival rates of all planted seedlings similarly performed well (85.4–100%).Twenty months after planting,*V. abyssinica* (84%) and *C. africana* (81%) revealedsignificantlyhigher (Log Rank; $p = 0.002$)survival rates. *G. robusta* (56.3%) and *C. macrostachyus* (45.8%) relatively shown poor survival rates.Seedlings withone and four months after planting revealedsignificantly ($p < 0.01$) higher survival rate than the other consecutive inventory periods. But, seedlings of four and seven months after planting had no difference in survival rate.The management regimes,fertilizer plus irrigation (T_6), irrigation plus weeding (T_8) and fertilizer plus irrigation and weeding (T_5) had better survival probabilities on *G. robusta* seedlings (Fig. 3). Similarly, *V. abyssinica* had higher survival probabilities when irrigated and weeded (T_8) than the control. The other managements revealed lower survival probabilities compared with the control. Seedlings of *V. abyssinica* that receive fertilizer plus irrigation (T_6) and weeding (T_4) revealed lower survival probabilities.*C. africana*had shown higher survival probabilities with the application of fertilizer (T_1) and irrigation (T_2).*C. macrostachyus*revealed higher survival probabilities in most of themanagement regimes than the control. But, had shown lower survival probabilities with the application of fertilizer plus irrigation (T_6) and combination of fertilizer plus irrigation and weeding (T_5) management regimes (Fig. 3).

Growth performance of seedlings

The seedlings had significant difference in height and root collar diameter (Table 1).*G. robusta* and *C. africana* revealed the highest root collar diameter and plant height. *V. abyssinica*had shown the least growth performance in the study. Timeand management significantly ($P < 0.05$) affected the growth performance of the species. Apart from main effects weeding and fertilizer, management regimes (treatments) revealed no interaction effects on growth performance of the tree species (Table 1). Besides, supplementation of water during the dry period had no effect on growth performance of tree species. Application of fertilizer significantly($P < 0.05$)affectedgrowth performance of the tree species. *V. abyssinica* revealed significantly lower growth performance in height and root collar diameter compared with the other tree species. Besides, higher plant height (189.5 and 163.8cm) of *C. africana* and *C. macrostachyus*wereobtained with fertilizer application than without fertilizer (80.8, and81.3 cm) respectively. These tree species were also sensitive to fertilizer application than other treatments used in this study explained by the existence of higher model coefficients (Table 2). Weeding had no significant effect on growth performance of the study species except on root collar diameter of *G.robusta*.Controling weed in *G. robusta*significantlyimproved its root collar diameter than other species used in this study. Moreover, *G. robusta* followed by *V. abyssinica* were sensitive to weeding explained by higher plant heightand root collar diametermodel coeficients compared to other species (Table 2). *V. abyssinica* revealed lower plant height (78.2, 60.2 cm) and root collar diameter (1.45, 0.95 cm) when weeded and not weeded respectively. Other tree species were observed to be less sensitive to weed indicated by nearly similar growth performance between weeded and not weeded seedlings of the same species.

Table 1

Effect of management regimes on growth performance of seedlings (ANOVA)

S.N	Source	Significance level (p < = 0.05)	
		Root collar diameter	Plant height
1	Species	0.001	0.001
2	Fertilizer	0.001	0.001
3	Water	0.128	0.657
4	Weed	0.008	0.001
5	Species * Fertilizer	0.001	0.001
6	Species * Water	0.692	0.067
7	Species * Weed	0.512	0.078
8	Fertilizer * Water	0.646	0.463
9	Fertilizer * Weed	0.596	0.395
10	Water * Weed	0.728	0.563
11	Species * Fertilizer * Water	0.624	0.189
12	Species * Fertilizer * Weed	0.309	0.264
13	Species * Water * Weed	0.782	0.353
14	Fertilizer * Water * Weed	0.625	0.442
15	Species * Fertilizer * Water * Weed	0.706	0.518

Table 2
Regression of plant height and root collar diameter with management regimes

Plant height model coefficients					
Tree species	**Constant**	**Fertilizer(a)**	**Water(b)**	**Weed(c)**	**Sig. level**
G.robusta	82.78	0.234	0.295	0.53	NS
V.abyssinica	41.3	0.49	0.04	0.281	NS
C.africana	79.625	0.874	0.074	0.091	**
C.macrostachyus	59.577	0.861	0.023	0.245	**
Root collar diameter model coefficients					
G.robusta	2.492	0.235	0.116	0.453	NS
V.abyssinica	0.9	0.354	0.142	0.264	NS
C.africana	2.383	0.726	0.126	0.093	**
C.macrostachyus	1.711	0.931	0.117	0.158	**

** Indicates model was significant at 0.001.

Moreover, fertilizer had significant ($P < 0.01$) and strong correlations with height ($r = 0.87$) and root collar diameter ($r = 0.77$) of *C. africana*. Likewise, fertilizer revealed significant ($p = 0.01$) and strong correlations with height ($r = 0.85$) and root collar diameter ($r = 0.87$) of *C. macrostachyus*.It had also significant ($P < 0.05$) correlation with height ($r = 0.48$) of *V.abyssinica*. Weeding had significant ($P < 0.05$) correlation with height ($r = 0.46$) and root collar diameter ($r = 0.52$) of *G. robusta*.Differently, *G. robusta* respondedwith insignificant and poor correlations to application of fertilizer.

Seedlings growth rate

There was significant difference in RGR of height and root collar diameter ($P < 0.01$) between tree species. *C. africana* significantly ($p < 0.05$) revealed the highest RGR (0.005 cm day^{-1}) of root collar diameterand plant height(Fig. 5) particulary during the early planting time.No differencewasdetected in height and root collar diameter growth rate between seedlings of *C. macrostachyus* and *G. robusta* (Fig. 5). *V. abyssinica* had revealed the least RGR of root collar diameter (0.002 cm day^{-1}) during the early planting time (Fig. 4). Management regimes and time had significant effect ($p < 0.05$) on relative growth rate (RGR) of height and root collar diameter of the tree species. The RGR of the study species was higher during the early planting time for both plant height and root collar diameter. This was during the first wet season (May to October) of the study area, while no significant response had shown in the subsequentsimilar wet season (Fig. 4). Seedlings with four months after planting had significantly ($p < 0.05$) higherRGR of root collar diameter in all species. Similarly, seedlings with seven months after planting revealed higher RGR in root collar diameter than eleven months after planting.

Management regimes revealed significantly ($p < 0.05$) higherRGR of plant height than the control (without management). Fertilizer application and irrigation management regimeshad significantly higher($p < 0.05$)growth rate on tree species plant height.Application of fertilizer plusirrigation and weeding (T_5)had significant effect ($p < 0.001$) on relative growth rate of the tree species heightcompared to the other management regimes. No significant difference in RGR of the species heightrevealed between irrigation plus weeding, control, and weedingmanagement regimes. Weeding and irrigationhad no difference ($p > 0.05$) in RGR of the tree species height compared with the control. Application of fertilizer plus irrigation and weeding (T_5)had significantly higher RGR of root collar diameter than the control.Moreover, weeding and irrigation had also no difference with the control (without management). Fertilizer and combination of other management regimes with fertilizer generally revealed significantly ($p < 0.05$) higher RGR in root collar diameter of the tree species.

Discussions

Survival and management regimes

Survival rate varies between and within species(Sinclair and Coe, 2019)and from site to site (Davis and Pinto, 2021). Seedlings survival was high during early plantations (Gebre et al., 2022)and stabilizes after the second year (Sukhbaatar et al., 2020).In the second and third years, survival rate declined slightly and remained unchanged in the fourth year (Shi et.al., 2019).Similarly, the overallsurvival ratein our study decreased from 100 to 45.8%twenty months after planting. Different survival rate values had reported for the same tree species in different time and areas.Authors such as Talema et al., (2019);Cheneke and Abdella, (2021); Gebre et al., (2022)reported relatively poor survival rate (37–68%) values of *G. robusta* and itagreeswith thecurrent study(56.3%). In contrary,Daba and Tadese, (2018)and Aschalew*et.al.*, (2023)reported higher survival rate values (80–100%) of*G. robusta* seedlings. Besides, Samuel and Kitaba*et.al*,(2017); Derero et al., (2021); Aschalew *et.al.*,(2023); Eshete et al., (2023)reported poor survival values (6-58.1%) of *C. africa*na seedlings. Others,Tafesse,(2007); Daba and Tadese, (2018); Kasaye et al., (2020)and Gebre et al., (2022)reported higher survival values (81.4–98%) of*C. africana* seedlings which is also consistent to our results (81%). Moreover, poor survival values (36.4–59.2%)of*C. macrostachyus*, had reported by Samuel, (2017) andDerero et al., (2021)and it was consistent with the results (45.8%) of this study.AuthorsKasaye et al., (2020) andAschalewet.al., (2023) reported highest survival rate values (80–100%) of*V. abyssinica*which was similar to the results (84%) of our study.

Different survival values were reported forthe tree species. Some of the reasons were the variability intimeof inventory after planting, the growing conditions of the area and management regimes applied.In agreement with our results, Daba and Tadese, (2018) reported no effect of irrigation frequencies and amount on survival values of *C. africana*and *G. robusta* tree species. Different survival values of *C. africana* with application of organic fertilizer (68–72%) and control (44%) was obtained in twelve monthsstudy time(Gebre et al., 2022).Besides, controlling weed had a positive effect on species establishment(Willoughby et al., 2006;Henkel-johnson et al., 2016; Alwi et al., 2020) and thesefiningswereconsistentwithourresearchresults.

Growth response and management regimes

Several post planting managementregimes affect growth performance of out planted seedlings(Magaju et al., 2020).Likewise,tree species respond differently to different post planting management regimes.Tadesse et al., (2021)reported the highest diameter and height growth of *G. robusta* and *C. africana* and lowest *C. macrostachyus* and *V. abyssinica* seedlings.Tamene, (2017)reported an annual height (80 cm) and root collar diameter (1.02 cm) of *G. robusta*.Similarly, Edo et.al., (2017) reported plant height of 80.6 to 88.9 cm for *G. robusta*and *C. africana*seedlings in a year. These findings were not different from the results of our study.

Most trees and shrubs have maximum growth rate during their first year of establishment (Talema et al., 2019). Similarly,Negash,(2010)stated fast growth for *V. abyssinica* particularly during its early growth and developmental stages.Gebre et al., (2022)stated that majority of species relative growth decreases with time. Kindu et al., (2006)also reported an earlier height and biomass increment than a later age.These literatures were consistent to our studies in that,tree species with four and seven months after planting revealed higher growth rate of root collar diameter and heightthan twenty months old. However, Birhane *et.al.*,(2020)indicated that tree species lacks consistency in growth to time response.

C. africana(0.005 cm day^{-1})and *G. robusta* (0.003 cm day^{-1})had the highest growth rate in root collar diameter and plant height particulary during the early planting time.Similar results were reported by Talema et al., (2019)for *G. robusta*growth rate (0.004 cm day-1).Tadesse et al., (2021)reported highest growth rates in diameter and height for *G. robusta* and *C. africana* species, while *C. macrostachyus* revealed the lowest growth rate in sub humid areas.This agrees with our results in that *V. abyssinica* had revealed the least in root collar diameter (0.002 cm day^{-1}) while no difference was detected in height growth rate between *G. robusta* and *V. abyssinica*.

Fertilizer had significanteffecton growth performance (height and root collar diameter) of the tree species.In agreement with thisEsekhade *et.al.*,(2013);Bahramov *et.al.*(2020); Kassa et.al., (2020); Yeshiwaset.al., (2021)and Gebre et al., (2022)reported that both inorganic and organic fertilizers increased growth performance of tree species.Aliarab *et.al.*,(2020)described that response of tree species to fertilizer depends on the fertility and moisture conditions of the soil.Alike, Byambadorj et al., (2020)stated fertilizer increased plant height with addition of wateringregimes,though, watering was not significant. This was similar toour results in that higher growth performance of tree species were attained with application of fertilizer while application of water was not significant. Smethurst, (2000)indicated soils that have enough nutrients may not respond to the applied fertilizerand even may interfere with metabolic processes and hinder growth.However, studies in the area (Dinssa and Elias, 2021) indicated low total nitrogen and available phosphorus contents both in the surface and subsurface soils of the study area.

Likewise, Esekhade et.al., (2013) found no difference between application of higher (200 kg of NPK/ha)and lower (100 kg of NPK/ha)fertilizer rateson growth performance of seedlings, while both rates weredifferent from the control (no application).

Moisture conservation structures improved height(95.83 ± 17.25 cm)and root collar diameter (2.5 ± 0.34 cm) of *C. africana*seedlings(Eshete *et al.*,2023). In agreement with this,Daba and Tadese, (2018) reported higher plant height and root collar diameter of*C. Africana*and *G. robusta*seedlingswith different watering regimes. Bhadouria *et al.*(2016)also stated that water availability is the most important limiting factor inearly growth of seedlings. These studies were not consistent with our results that revealedwatering had no effect on growth performance of the tree species. This may be attributed to the coincides of planting timewith the onset of rainfall and hence, no soil moisture problem for the consecutive three to four establishment months in our study area.Soil moisture improves the availability of soil nutrients to plants and hence, promotes faster early growth performances of tree species than late as also reported by many different authors.

Besides, controlling weed significantly affected height and diameter of tree species (Naeem, and Schroeder, 2017). Weeds compete for light, moisture, and nutrients and thus, removal of weeds through frequent hoeing is essential for good early growth of seedlings (Vollmann et.al., 2010 andRabbani et.al., 2011).Unless regular weeding is ensured, lapse in controlling weed during early stages of establishment caused reductions in growth and establishment of tree species (Alwi et al., 2020). Weeds could reduce plant growth and, consequently delay the time required for plants to reach maturity. Tree species frequently weeded (12 times per year) consistently recorded the highest growth in height (65.1-158.1 cm) between three and twelve months after planting (Esekhade *et.al.*,2013).On the contrary, Stokes *et al.*, (2014)found that weed control had no effect on survival, height and diameter growth of tree species. In our case, some of the tree species were sensitive (*G. robusta* and *V. abyssinica*) while some less sensitive (*C. africana* and *C. macrostachyus*) to weeding.Stokes *et al.*, (2014)stated the existence and magnitude of benefits from controlling weed is highly site and species dependent.Moreover, the type and intensity of weed also affects the level of impact.

Conclusion

The tree species varied in their survival and growth rates. Management regimes and time had affectedgrowth and survival ofthe tree species. Apart frommain effects fertilizer and weeding, management regimes revealed no interaction effects.Seedlings with one and four months after planting had better survival and growth performances than twenty months after planting. The variation in growth performance could be attributed to the lack of continuous (e.g., every growing season) application of fertilizer. During early planting time, mostly there is no moisture problem and when fertilizer is applied during that growing seasonit is reasonable to attain better growth rates. Weeding had significant correlation with height and root collar diameter of *G. robusta*seedlings.Fertilizer had also significant and strong correlations with height and root collar diameter of *C. africana*and*C. macrostachyus*.Higher plant height and root collar diameter of *C.africana* and *C.macrostachyus*were obtained with application of fertilizer. *V. abyssinica* had significantly revealed the lowestgrowth performance compared to the other species. The growth rate of the study species was higher during the early planting months for both plant height and root collar diameter.Generally, management regimeshad improved growth and survival of the tree species compared with the control (without managements). The response of tree species to management interventions are site specific and hence, identifying the main survival and growth limiting factors is crucial for a better survival and growth of seedlings. As the fertilizer requirement of tree species varies, development of asoil test based appropriate fertilizer rate and type is essential. Moreover, each growth stage of the tree species demands different management intervention (for example applying fertilizer once during the establishment year only may not be enough, it may need the same or different amount of fertilizer and irrigation and other managements in the consecutive years). Effect of weed type and density on growth performance of tree species also need to be studied

Declarations

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References

1. Abera, T., Feyisa, D.and Friesen, D. K. (2009). Effects of Crop Rotation and N-P Fertilizer Rate on Grain Yield and Related Characteristics of Maize and Soil Fertility at Bako , Western Oromia , Ethiopia', 3, pp. 70–79. 'East African Journal of Sciences (2009)
2. Agathokleous, E. Kitao, M., Komatsu, M., Tamai, Y. Harayama, H., Koike, T. (2023) 'Single and combined effects of fertilization , ectomycorrhizal inoculation , and drought on container grown Japanese larch seedlings', Journal of Forestry Research, 34(4), pp. 1077–1094. Available at: https ://doi.org /10.1007/ s11676-022-01565-3.
3. Aliarab, A., Vazifekhah, E.O., Sadati, S.E. (2020) 'Effect of soil moisture content and nitrogen fertilizer on survival growth and some physiological characteristics of Platycladus orientalis seedlings', Journal of Forest Science, 66(12), pp. 511–523. Available at https://doi.org/10.17221/34/2020-JFS.
4. Alwi, A., Lapammu, M. Jarapudin, Y., Molony, K., Boden, D., Macdonell, P., Warburton, P., Brawner, J., & Meder, R. (2020) 'Importance of weed control prior to planting for the establishment of planted forests in', 32(4), pp. 349–354.

5. Amha, Y., Mehari, A., Tesfaye, Z., Kassa and Argaw, M. (2020) ‘Growth and biomass production of some selected native and introduced tree / shrub species under severely degraded landscapes of west showa zone of oromiya regional state central highlands of Ethiopia’, 4(1), pp. 28–34. Available at: https://doi.org/10.15406/freij.2020.04.00096.
6. Aschalew, E., Sintayo, D., and Temesgen, G. (2023) ‘species for promotion of agroforestry practice at bore district , growth performance evaluation of multipurpose tree and shrub species for promotion of agroforestry practice at bore district (July). Available at: https//doi. org/10.24941/ ijcr. 41927.07.2021.
7. Bahramov, R., Mamatyusupov, A., Tokhtaboeva, F.,Khomidov, J., and Yuldashev, H. (2020) ‘A comprehensive application of fertilizers for growing plantations in forest nurseries : A brief review A comprehensive application of fertilizers for growing plantations in forest nurseries : A brief review’, Earth and Environmental Science [Preprint]. Available at: https://doi.org/10.1088/1755-1315/614/1/012117.
8. Bhadouria, R., Singh, R., Srivastava, P., Raghubanshi, A.S. (2016) ‘Understanding the ecology of tree-seedling growth in dry tropical environment: a management perspective’, Energy, Ecology and Environment, 1(5), pp. 296–309. Available at: https://doi.org/10.1007/s40974-016-0038-3.
9. Birhane, E., Tesfaye, M.A. and Kim, D.G. (2020) ‘Deforestation and Forest Degradation in Ethiopia and Intervention Measures’, (August, 2022).
10. Bland, J.M. and Altman, D.G. (1998) ‘Survival probabilities (the Kaplan-Meier method).’, BMJ (Clinical researched.) ,317(7172) p. 1572. Available at :https://doi.org/10.1136/bmj.317.7172.1572.
11. Bonin, C.L., Fidel, R.B. and Laird, D.A. (2018) ‘Perennial biomass crop establishment , community characteristics , and productivity in the upper US Midwest : Effects of cropping systems seed mixtures and biochar applications’. Available at: https://doi.org/10.1016/j.eja.2018.08.009.
12. Boreux, V., Vaast, P. and Madappa, L.P. (2016) ‘Agroforestry coffee production increased by native shade trees, irrigation, and liming, Agronomy for Sustainable Development [Preprint], (April 2019). Available at: https://doi.org/10.1007/s13593-016-0377-7.
13. BWAO (Bako-Tibe Woreda Agricultural Office), 2020. Annual Report Document for the year 2019/2020 production period.
14. Byambadorj, S.O., Chiatante, D., Akhmadi, K., Lunten, J., Ochirbat, B., Park, B.B., Scippa, G.S., Montagnoli, A., and Osor, B.N. (2020)‘ The effect of different watering regimes andfertilizer addition on the growth of tree speciesused to afforest the semi-arid steppe of Mongolia: Available at: https://doi.org/10.1080/11263504.2020.1779845.
15. Cheneke, B., and Abdella, M. (2021) ‘and Academic Review Growth Performance Evaluation of Multipurpose Tree Species under Dire Dawa’, International Journal of Current Research and Academic Review, 9(3), pp. 89–96. Available at: https://doi.org/https://doi.org/10.20546/ijcrar.2021.903.009.
16. Daba, M.H. and Tadese, A.E. (2018) ‘Estimation of Optimum Water Requirement and Frequency of Watering for Different Tree Seedlings at Bako Agricultural Research Center Nursery Site, (January).

Available at: https://doi.org/10.11648/j.jher.20170306.11.

17. Dabesa, A. and Tana, T. (2021) ‘Response of Soybean (Glycine max L (Merrill) to Bradyrhizobium Inoculation , Lime , and Phosphorus Applications at Bako , Western Ethiopia’, 2021.
18. Davis, A.S. and Pinto, J.R. (2021) ‘The Scientific Basis of the Target Plant Concept : An Overview’, pp. 1–13.
19. Degef, K., Abebe, G. and Biru, G. (2023) ‘Tef value chain analysis in western Oromia , Ethiopia : evidence from Tef producers and traders’. Available at: https://doi.org/10.15651/2408-5510.23.11.418.
20. Derero, A., Coe, .R., Muthuri, C.,Hadgu, K.M., Sinclair, F. (2021) ‘Early growth performance of Cordia africana Lam . in provenance and progeny Plantation and Agroforestry Research Directorate Working Paper Series 03 / 2019 Early growth performance of Cordia africana Lam. in provenance and progeny tests at Tepi , south-w’, (May). Available at: https://doi.org/10.13140/RG.2.2.24023.60324.
21. Dinssa, B. and Elias, E. (2021) ‘Characterization and classification of soils of Bako Tibe District, West Shewa, Ethiopia: Available at: https://doi.org/10.1016/j.heliyon.2021.e08279.
22. Edo, G.Y., Gebremedihn, K.G., Woldsenbet, A.F., Guta, K. K., (2017) ‘Growth Performance of Some Multipurpose Tree Species Around the Homesteads in Gimbo District Southwestern Ethiopia’, (January). Available at: https://doi.org/10.11648/j.aff.20170601.11.
23. Esekhade, T.U., Okore, I.K., Ogidi, E.G.O. and Arasowan, J. (2013) ‘Effect of weeding frequency on the growth performance and budding success of hevea seedling effect of weeding frequency and fertilizer rates on the growth performance and budding successes of hevea rootstock’, (February 2016).
24. Eshete, A., Teshome, S., Edaso, A., Yilma, G., and Furo, G. (2023) ‘Selection of Soil and Water Conservation Technologies and Native Tree Species for Rehabilitation of Degraded Arid Lands in Southeast Ethiopia’, 2023.
25. Gazoulis, I.; Kanatas, P.; Papastylianou, P.; Tataridas, A.; Alexopoulou, E.; Travlos,. (2021) ‘Weed Management Practices to Improve Establishment of Selected Lignocellulosic Crops’, pp. 1–16.
26. Gebre, T., Chinthapalli, B., Anjulo, M., Robinson, D. (2022). The impacts of post plantation management practices on growth and survival rate of selected tree species in Mirab Abaya District, Southern Ethiopia: An experimental approach’, 14(September), pp. 28–41. Available at: https://doi.org/10.5897/JHF2022.0693.
27. Henkel-Johnson, D., Macdonald, S.E., Bork, E.W. Thomas, B.R. (2016) ‘Forest Ecology and Management Influence of weed composition , abundance , and spatial proximity on growth in young hybrid poplar plantations’, forest ecology and management, 362, pp. 55–68. Available at: https://doi.org/10.1016/j.foreco.2015.11.010.
28. Hoffmann, W.A.and Poorter, H. (2002) ‘Avoiding Bias in Calculations of Relative Growth Rate’, (2), pp. 37–42. Available at: https://doi.org/10.1093/aob/mcf140.
29. Hussen, C.H. and Geleta, F.T. (2021) ‘Research Article Factors Affecting Smallholder Farmers Participations in Cluster Crop Production: Evidence from Selected Districts of West Shewa Zone,

Oromia National Regional State, Ethiopia', 37(3).

30. Kasaye,M. Abebe, G., Abiyu, A. Wondie,M., Belay, B.(2020) 'Selection of Different Trees / Shrubs Species for Rehabilitation of Degraded Lands in Wag-Lasta Area , Northeastern Ethiopia Journal of Forest Research : Open Access', (October).
31. Kassa, G., Ferde, T. and Nigatu, A. (2020) 'Improving growth and productivity of Cordia africana trees using moringa leaf juice in north western Ethiopia Improving growth and productivity of Cordia africana trees using moringa leaf juice in north western Ethiopia', Cogent Food & Agriculture, 6(1). Available at: https://doi.org/10.1080/23311932.2020.1762980.
32. Keba, W., Tolemariam, T. and Mohammed, A. (2022) 'I P of', Heliyon, p. e10433. Available at: https://doi.org/10.1016/j.heliyon.2022.e10433.
33. Kindu, M., Glatzel, G., Tadesse, Y., Yosef, A. (2006) 'tree species screened on nitosols of central ethiopia : biomass production , nutrient contents and effect on soil nitrogen', 18(3), pp. 173–180.
34. Kitaba, F., Mama, T. and Negese,W. (2017) 'Adaptation and Growth Performance of Multipurpose Trees Under Haro Sebu Condition', 7(23), pp. 13–18.
35. Lemenih, M. and Kassa, H. (2014) 'Re-Greening Ethiopia: History, Challenges and Lessons', pp. 1896–1909. Available at: https://doi.org/10.3390/f5081896.
36. Lu, Y., Duursma, R.A., Farrior, C.E., Medlyn, B.E. and Feng, X.2019) 'Optimal stomatal drought response shaped by competition for water and hydraulic risk can explain plant trait covariation', (1977). Available at: https://doi.org/10.1111/nph.16207.
37. Magaju, C., Winowiecki, L.A., Crossland, M., Frija, A., Ouerghemmi, H., Hagazi, N., Sola, P., Ochenje, I., Kiura, E., Kuria, A., Muriuki, J, Carsan, S., Hadgu, K., Bonaiuti, E., and Sinclair, F. (2020) 'Assessing Context-Specific Factors to Increase Tree Survival for Scaling Ecosystem Restoration Efforts in East Africa', pp. 1–20.
38. Mezgebu, M. (2023) 'Assessment of agroforestry practices in Buno Bedele and Ilu Abba Bora zone of Oromia region , Ethiopia', pp. 1–20.
39. Mganga, K.Z. Nyariki, D.M., Musimba, N.K.R., Amwata, D.A. (2018) 'Determinants and rates of land degradation : Application of stationary time-series model to data from a semi-arid environment in Kenya', 10, pp. 2017–2018.
40. Naeem, H. and Schroeder, W.R. (2017) 'Effect of weed control methods on growth of five temperate agroforestry tree species in Saskatchewan', 93, pp. 271–281.
41. Negash, L. (2010) Indigenous Trees, Ethiopia, Addis Ababa University Press.
42. Oliet J.A., Fu, Y., Li, G., Wang, J. (2017) 'Effect of controlled release fertilizer type and rate on mineral nutrients, non-structural carbohydrates, and field performance of Chinese pine container-grown seedlings', 51(2), pp. 1–13.
43. Rabbani, N., Bajwa, R. and Javaid, A. (2011) 'Interference of five problematic weed species with rice growth and yield', African Journal of Biotechnology, 10(10), pp. 1854–1862. Available at: https://doi.org/10.5897/AJB10.1866.

44. Ribamar, J.O., Dionisio, L.F., Auca, E.C., Schwartz, G., Gomringer, R.C. (2022) ‘Forestry performance of Bertholletia excelsa Humn& Bonpl Lecythidaceae under different fertilizers after two years of planting’, pp. 20–28. Available at: https://doi.org/10.5747/ca.2022.v18.n1.a475.
45. Samuel, D. (2017) ‘Initial Growth Responses of Multipurpose Tree Species Under Termite Infested Areas at Mana Sibu District of West Wollega Zone , Oromia Regional State , Ethiopia’, 5(5), pp. 134–139. Available at: https://doi.org/10.11648/j.ajls.20170505.13.
46. Shehab, A.A., Guo, Y. (2019) ‘Effects of nitrogen fertilization and drought on hydrocyanic acid accumulation and morpho-physiological parameters of sorghums’, pp. 0–2. Available at: https://doi.org/10.1002/jsfa.10965.
47. Shi, W., Grossnickle, S.C., Li, G., Su, S., and Liu, Y. (2019) ‘Fertilization and irrigation regimes in fl uence on seedling attributes and fi eld performance of Pinus tabuliformis Carr’, (September 2018), pp. 97–107. Available at: https://doi.org/10.1093/forestry/cpy035.
48. Sinclair, F. and Coe, R.I.C. (2019) ‘the options by context approach: a paradigm shift in agronomy’, Experimental Agriculture, 55(S1), pp. 1–13. Available at: https://doi.org/10.1017/S0014479719000139.
49. Smethurst, P.J. (2000) ‘Soil solution and other soil analyses as indicators of nutrient supply : a review’, 138.
50. Sorecha, E.M. (2017) ‘Growth and survival rate of endemic trees of Ethiopia : Olea africana and Hagenia abysinicca in Lake Haramaya Watershed , Eastern Ethiopia’, 9(5), pp. 33–39. Available at: https://doi.org/10.5897/ jhf 2017.0486.
51. Stokes, V.J. and Willoughby I. H. (2014) ‘Early weed control can increase long-term growth, yield and carbon sequestration of Sitka spruce stands in Britain’, An International Journal of Forest Research, (February), pp. 425–435. Available at: https://doi.org/10.1093/forestry/cpu001.
52. Sukhbaatar, G., Ganbaatar, B., Jamsran, T., Purevragchaa, B., Nachin, B., Gradel, A. (2020) ‘Assessment of early survival and growth of planted Scots pine (Pinus sylvestris) seedlings under extreme continental climate conditions of northern Mongolia’,Journal of Forestry Research, 31(1), pp. 13–26. Available at: https//doi.org/10.1007/s11676-019-00935-8.
53. Tadesse, S., Gebretsadik, W., Muthuri, C., Derero, A., Hadgu, K.M., Said, H., . Dilla, A. (2021) ‘Crop productivity and tree growth in intercropped agroforestry systems in semi-arid and sub-humid regions of Ethiopia’, Agroforestry Systems, 95(3), pp. 487–498. Available at: https://doi.org/10.1007/s10457-021-00596-9.
54. Tafesse, M. (2007) ‘school of graduate studies growth performance of three indigenous and one endemic tree species of ethiopia on a degraded site in central-west ethiopia’.
55. Talema, A., Poesen, J., Muys, B., Padro, R., Dibaba, H., Diels, J. (2019) ‘Survival and growth analysis of multipurpose trees shrubs and grasses used to rehabilitate badlands in the subhumid tropics, (November 2018), pp. 470–480. Available at: https://doi.org/10.1002/ldr.3239.
56. Tamene, W.G. (2017) Germination and early growth performances of cordia africana lam. in potted vertisol and nitosol in bichena town, east gojjam zone, Amhara regional state.

57. Tulu, A., Diribsa, M., Fekede,G., Temesgen,W., Keba,W.,and Kumsa, A. (2021) ‘Comparative Evaluations of Selected Pigeon Pea (Cajanus cajan) Genotypes for Biomass Yield , Nutrient Composition , and Dry Matter Intake under Diverse Locations of Tropical Africa’, 2021.
58. Uscola, M., Salifu, K.F., Oliet, J.A., Jacobs, D.F. (2015) An exponential fertilization dose response model to promote restoration of the Mediterranean oak Quercus ilex’, New Forests Available at: https //doi.org/10.1007/s11056-015-9493-5.
59. Villar-salvador, P., Uscola, M. and Jacobs, D.F. (2015) ‘in the growth and stress tolerance of planted forest trees’, New Forests [Preprint]. Available at: https://doi.org/10.1007/s11056-015-9499-z.
60. Vollmann, J., Wagentristl, H. and Hartl, W. (2010) ‘The effects of simulated weed pressure on early maturity soybeans’, European Journal of Agronomy, 32(4), pp. 243–248. Available at: https://doi.org/10.1016/j.eja.2010.01.001.
61. Wariyo, Z.D. and Negewo, D.A. (2023) ‘East African Journal of Forestry & Agroforestry Coffee Shade Tree Selection Criteria and Management Techniques in Smallholder Coffee-Based Agroforestry System in Gomma Woreda , Southwest of Ethiopia’, 6(1), pp. 84–97. Available at: https://doi.org/10.37284/eajfa.6.1.1126.
62. Willoughby, I., Clay, D.V., Dixon, F.L., Morgan, G.W. (2006) ‘The effect of competition from different weed species on the growth of Betula pendula seedlings’, 1912, pp. 1900–1912. Available at: https://doi.org/10.1139/X06-075.
63. Yeshiwas, Y., Yikeber, B., Zewdie, B., Chekol, A. and Walle, A. (2021) ‘Effect of Nitrogen Fertilizer and Farmyard Manure on Growth and Yield of Lettuce (Lactuca sativa L .) Role of Nitrogen fertilizer and Farm yard manure on Lettuce’, (February 2018). Available at: https://doi.org/10.3923/ijar.2018.74.79.

Figures

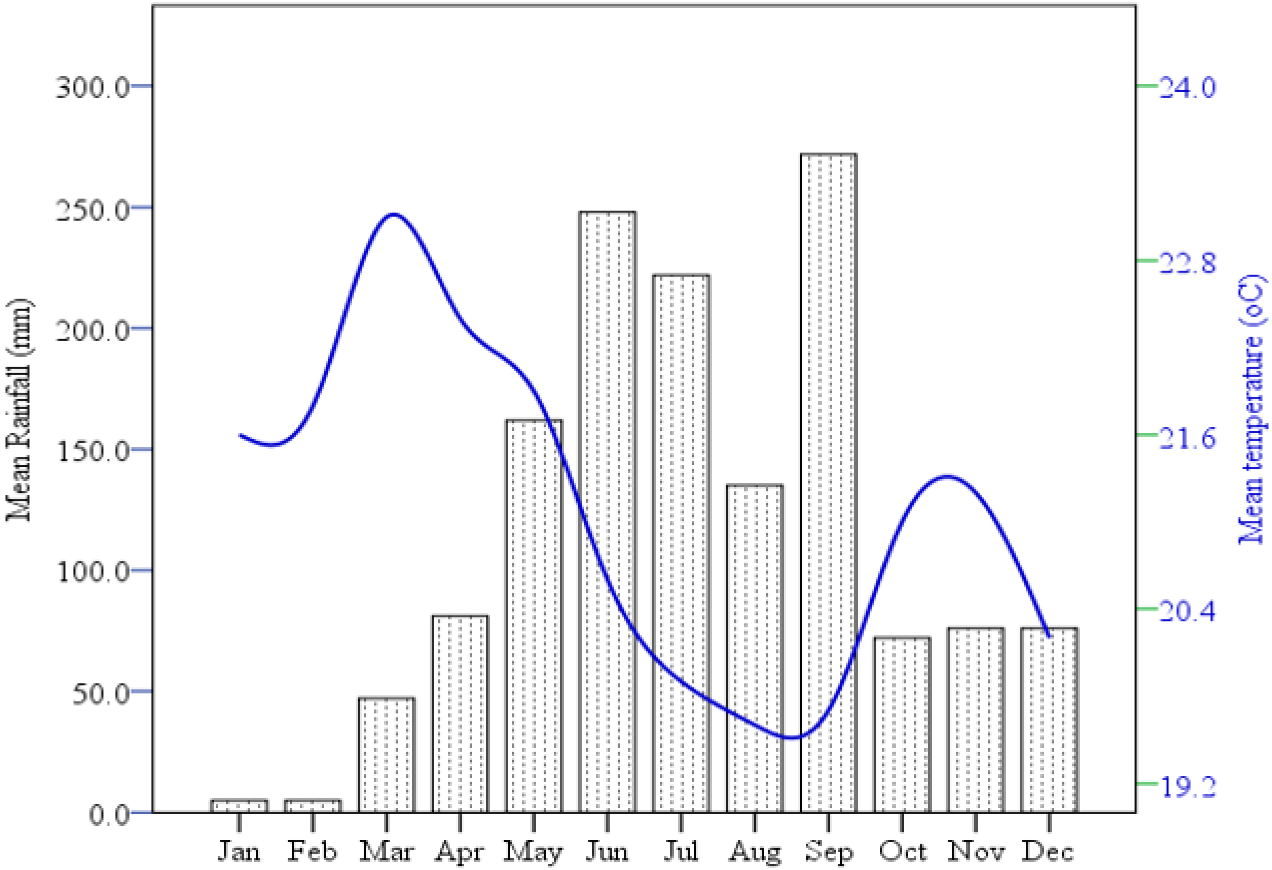

Figure 1

Monthly temperature and rainfall of the study area

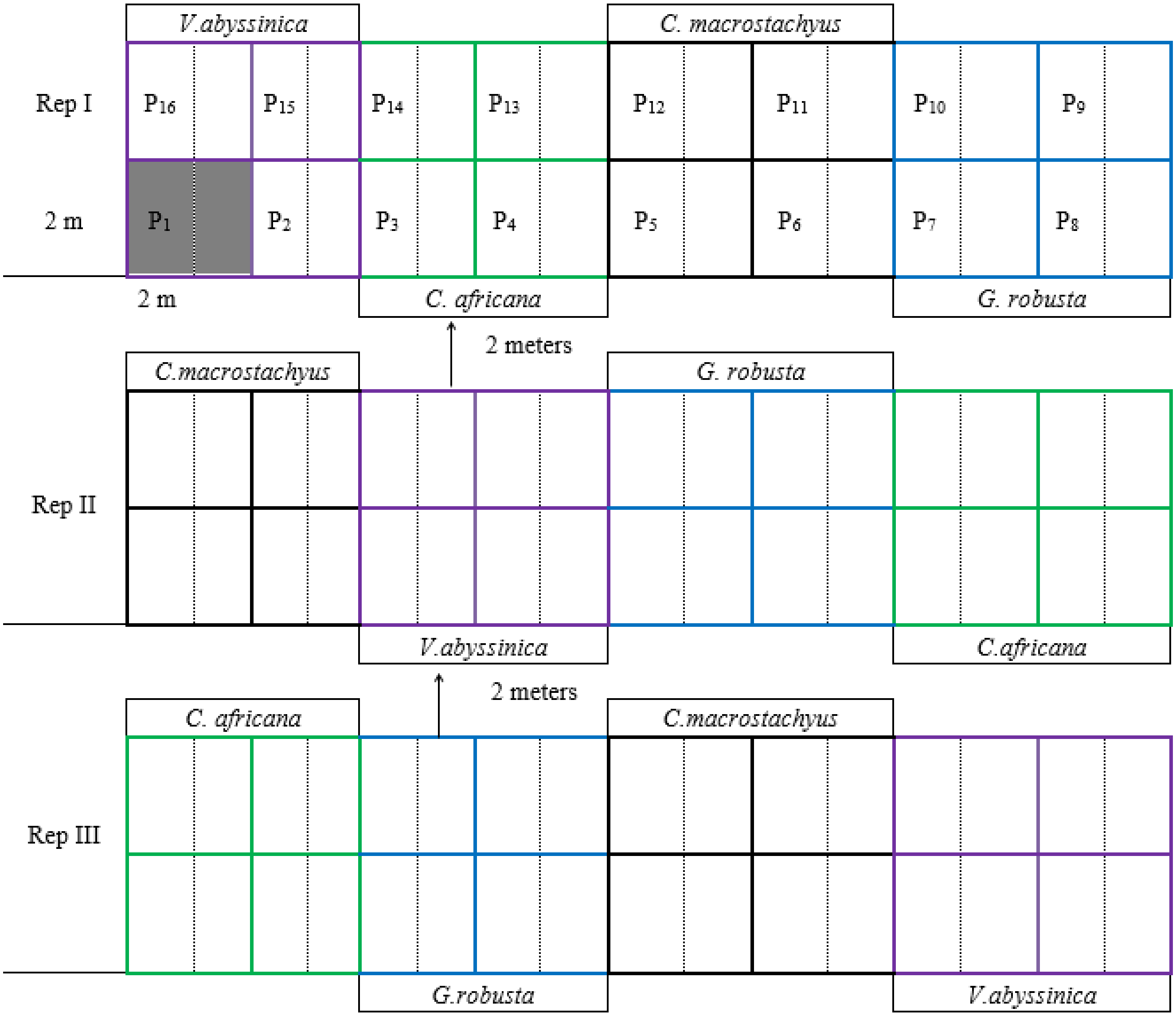

Figure 2

Field layout of the experiment at Bako district, western Oromia

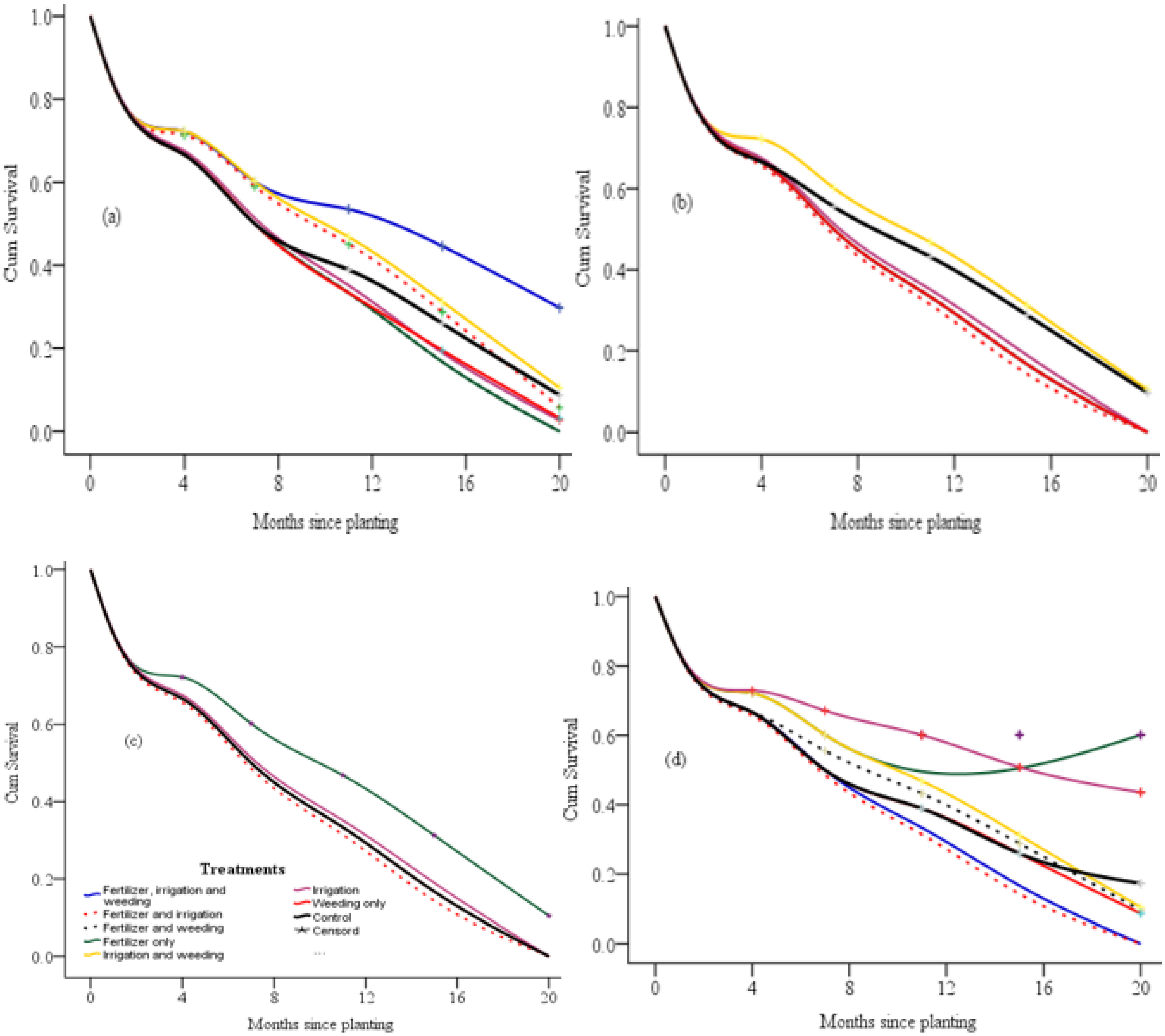

Figure 3

Kaplan-Meier survival curve of *G. robusta*(a),*V. abyssinica*(b),*C. africana*(c),and *C. macrostachyus* (d) tree species

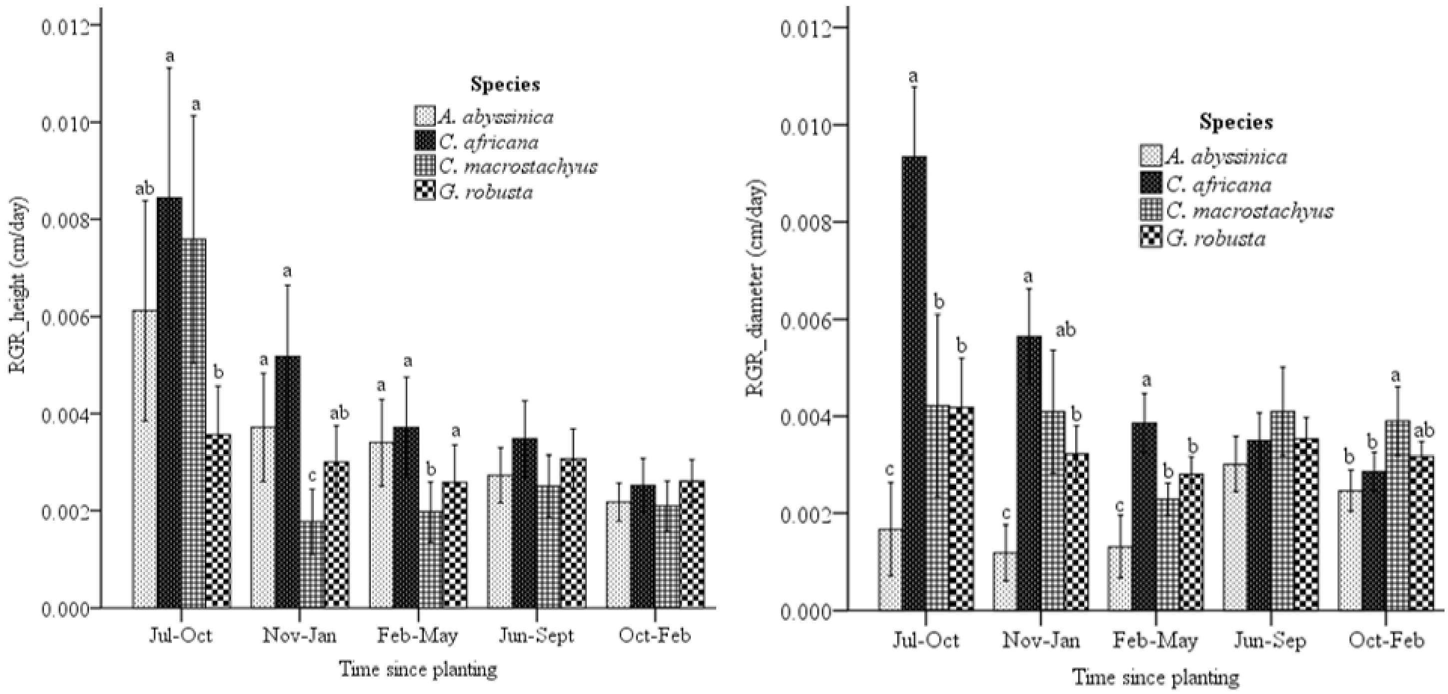

Figure 4

RGR of plant height (left) and RCD (right) of the differenttree species.

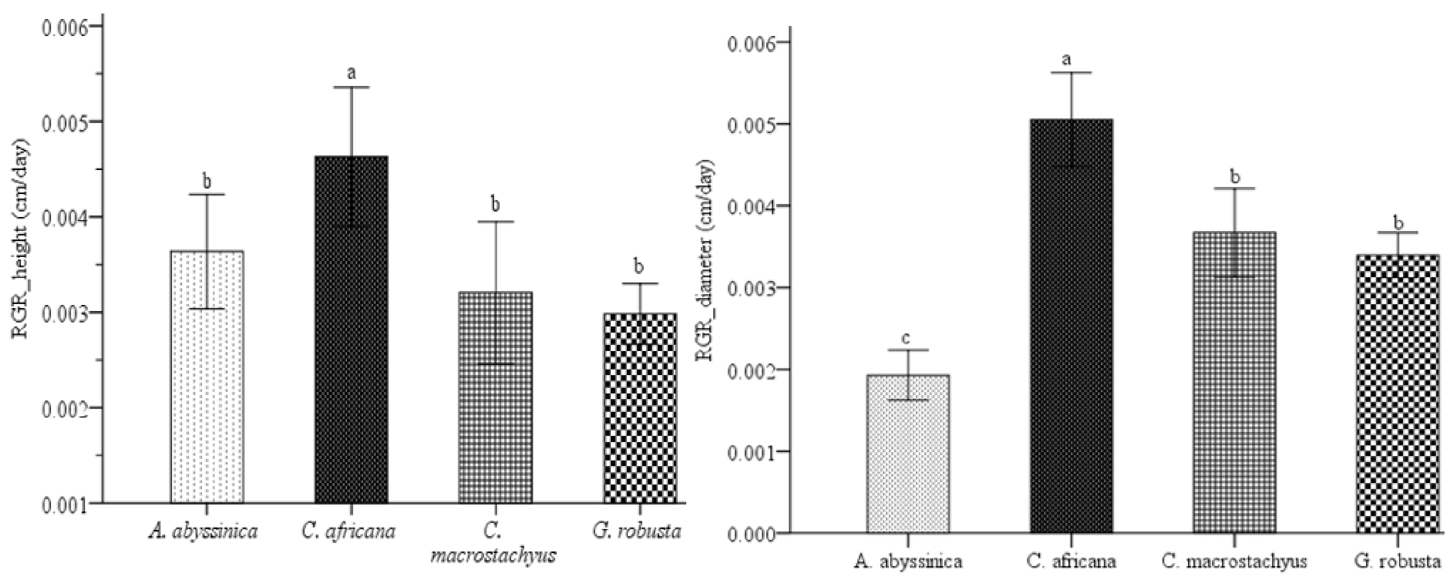

Figure 5

RGR of plant height (left) and RCD (right) of the different tree species.