JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
ISSN: 2339-076X (p); 2502-2458 (e), Volume 6, Number 4 (July 2019):1861-1873
DOI:10.15243/jdmlm.2019.064.1861

Research Article

Early growth and survival of different woody plant species established through direct sowing in a degraded land, Southern Ethiopia

Shiferaw Alem*, Hana Habrova

Department of Forest Botany, Dendrology and Geo-biocenology, Mendel University in Brno, Zemedelska 3/61300, Brno, Czech Republic

*corresponding author: shife19@gmail.com

Received 2 May 2019, Accepted 30 May 2019

Abstract: In addition to tree planting activities, finding an alternative method to restore degraded land in semi-arid areas is necessary, and direct seeding of woody plants might be an alternative option. The objectives of this study paper were (1) evaluate the growth, biomass and survival of different woody plant species established through direct seeding in a semi-arid degraded land; (2) identify woody plant species that could be further used for restoration of degraded lands. To achieve the objectives eight woody plant species seeds were gathered, their seeds were sown in a degraded land, in a randomized complete block design (RCBD) (n=4). Data on germination, growth and survival of the different woody plants were collected at regular intervals during an eleven-month period. At the end of the study period, the remaining woody plants' dry biomasses were assessed. One-way analysis of variance (ANOVA) was used for the data analysis and mean separation was performed using Fisher's least significant difference (LSD) test (p=0.05). The result revealed significant differences on the mean heights, root length, root collar diameters, root to shoot ratio, dry root biomasses and dry shoot biomasses of the different species ($p < 0.05$). There were also variations among species in their germination, dry biomasses and survival. The survival of the woody plants was inversely correlated with air temperature. Of the species studied, four tree species, *Dodonaea angustifolia*, *Vachellia tortilis*, *Vachellia seyal* and *Vachellia nilotica*, were successful in growing in the degraded land; and therefore, we recommend these for restoration projects.

Keywords: *biomass, degraded land, direct sowing, growth, survival, woody plants*

To cite this article: Alem, S. and Habrova, H. 2019. Early growth and survival of different woody plant species established through direct sowing in a degraded land, Southern Ethiopia. J. Degrade. Min. Land Manage. 6(4): 1861-1873, DOI:10.15243/jdmlm.2019.064.1861.

Introduction

Land degradation is defined as substantial, decrease in land's biological productivity and/or usefulness to humans (Johnsen and Lewis, 2007). It includes all processes that diminish the capacity of land resources to perform essential functions and services in ecosystems (Johnson et al., 1997; Hurni et al., 2010). According to Berry (2003), land degradation involves two interlocking complex systems: the natural ecosystem and the human social system. There is a growing global awareness that land degradation is as much a threat to environmental well-being as more obvious forms of damage such as deforestation and pollution (Greenland and Szalbocs, 1994; Taddese, 2001). Moreover; it can affect food security and the wealth of nations (Bezuayehu et al., 2002).

Land degradation problems can be prevented by using various mechanisms depending on the nature and form of degradation (Gashaw et al., 2014). The main principles for reducing land degradation are maximizing vegetation cover to prevent erosion, replacing nutrients removed, and putting in place structures (terraces, contour bunds, vegetation strips) to reduce the speed and volume of water flow over the soil (Coxhead and Øygard, 2008). Re-vegetating disturbed or reclaimed lands often consists primarily of planting trees and shrubs from container stock that can be costly to buy or produce, time-consuming to plant (additional cost), and logistically difficult for large restoration projects (Lamb et al., 2005; Chazdon, 2008; Palmerlee and Young, 2010). It is also crucial to select appropriate species for afforestation of the degraded land (Li et al., 2012). Exclosures have also been identified as a valuable rehabilitation option when the main driver of land degradation is grazing (Mekuria and Ayenekulu, 2011), but they can take substantial time to achieve rehabilitation depending on many factors.

Direct seeding is another method to restore degraded lands (Ochsner, 2001; Stromberg et al., 2007). Sowing seeds directly in the field, instead of growing plants from them in the nursery, save on nursery costs, transportation of seedlings and laborious planting processes (Ochsner, 2001; Stromberg et al., 2007; Smidth, 2008). There are also other advantages of direct seeding over planting seedlings, including transplantation stress avoidance, enabling seedling root system development without the restrictions of a pot and the possible adverse effects of root pruning, and the possibility of vegetating inaccessible areas (Ochsner, 2001; Smidth, 2008). However, this technique also has its own disadvantages: the soil can dry out too rapidly and also the soil has low nutrient levels that result seedling mortality or poor germination, and competing vegetation may be a problem for survival and growth for a longer time period (Spittlehouse and Stathers, 1990; Smidth, 2008; Anaya-Romero et al., 2015). Cardoso et al. (2015) found in their study that *Plukenetia volubilis* seedlings survival was affected by the temperature, and 35°C significantly reduced seedling survival (52%) compared to temperatures of 25 and 30°C.

A review of published work on direct seeding of different species in different areas reveals varied results on the survival and growth of different woody plants (Hoper et al., 2002; Douglas et al., 2007; Wang et al., 2011; Navarro, 2006; Cole et al., 2011; Laborde and Corrales-Ferrayola, 2012; St-Denis et al., 2013; Hossain et al., 2014). Much of the literature on the potential of direct seeding of woody plant species has been focused on the dry tropics (Laborde and Corrales-Ferrayola, 2012), tropical mountains (Cole et al., 2011); lignite mines (Hossain et al., 2014), areas under plantation canopies (Wang et al., 2011), pasturelands (Douglas et al., 2007), and; abandoned farmlands (Hooper et al., 2002; St-Danis et al., 2013). Studies that evaluate the success of direct seeding of different woody plant species on lands heavily degraded by erosion are lacking. The present study aimed to address this lack by evaluating the potential of various woody plants for revegetation of degraded land through direct seeding.

The woody plants selected for these studies are indigenous species that provide various benefits (medicinal, agroforestry, food, biological conservation, etc.) and which can grow in a wide range of ecological conditions (Table 1). The specific objectives of the study were to: (1) evaluate the growth and survival of different woody plant species established through direct seeding on degraded land; (2) identify woody plant species that could be further used for ecological restoration of degraded lands; and (3) evaluate the relationship between air temperature and seedling survival. The hypotheses of the study were 1) all the selected woody plant species established through direct seeding will have a high germination and survival in the degraded land. (2) air temperature of the study area will not have an effect on the survival of the woody plant species established through direct seeding in the degraded land.

Materials and Methods

The study area

The study was performed in Kajimma Umbullo Kebele, Sidama Zone, Southern Nations, Nationalities and People Regional state of Ethiopia. The study site is located at 7º 1′45′′ N and 38º 16′30′′ E (Figure 1). According to Giorgis (2014) classification, the study area lies in a semi-arid region. The area has an altitude of 1700 meter above sea level (m. a.s.l). The mean annual rainfall (in the years 1993-2012) of the area was 959 mm, and its mean minimum and mean maximum monthly air temperatures were 12 ºC and 26 ºC, respectively (Figure 2). The dominant soil types of the study area are well-drained eutric and haplic cambisols (Tiki and Tadesse, 2015). Well- to excessively drained, deep to very deep, medium- and course-textured vitric andosols are also developed on the area's flat to gently undulating topography and rolling plains (Tiki and Tadesse, 2015) in the area.

The topsoil of the area where the field study was performed was heavily degraded (up to a depth of 1 metre), because of soil erosion problems due to loss of vegetation cover in the area (Figure 3A). According to informal discussions with elders, the study area was once covered by a dense forest. Tiki and Tadesse (2015) in their study also indicated that the dominant tree species near to the study area were mainly

Vachellia and Ficus species. The elders further stated that at the beginning of 1990, the communities around the study area cut the trees for fuelwood and house construction purposes. As a result of loss of vegetation cover, the soil erosion was expanded and bigger gullies were formed.

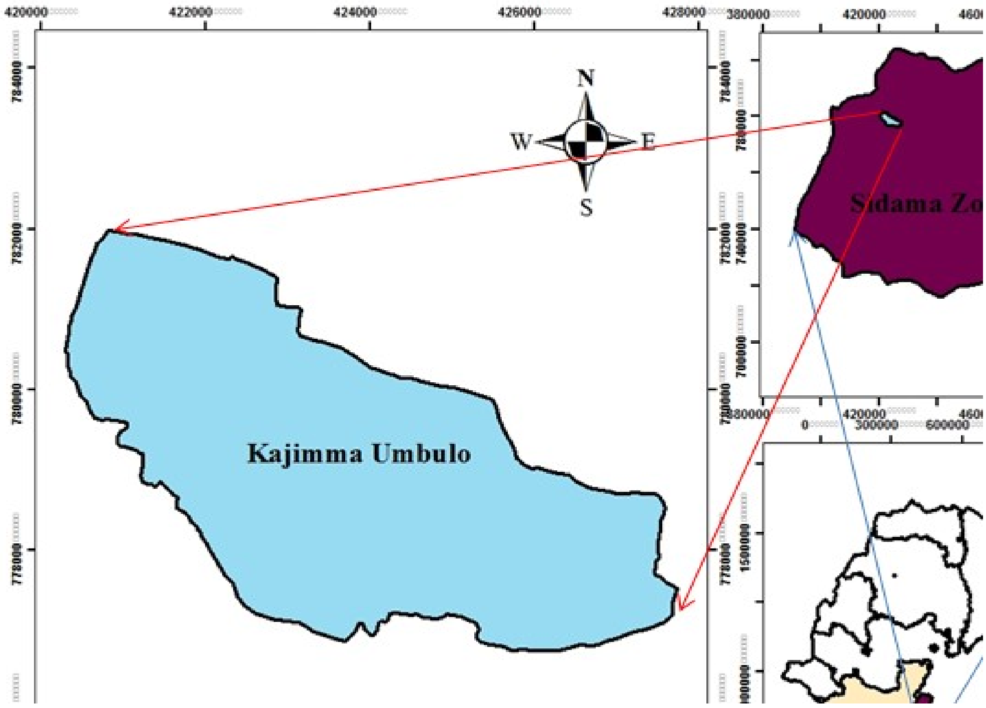

Figure 1. Location of the study area.

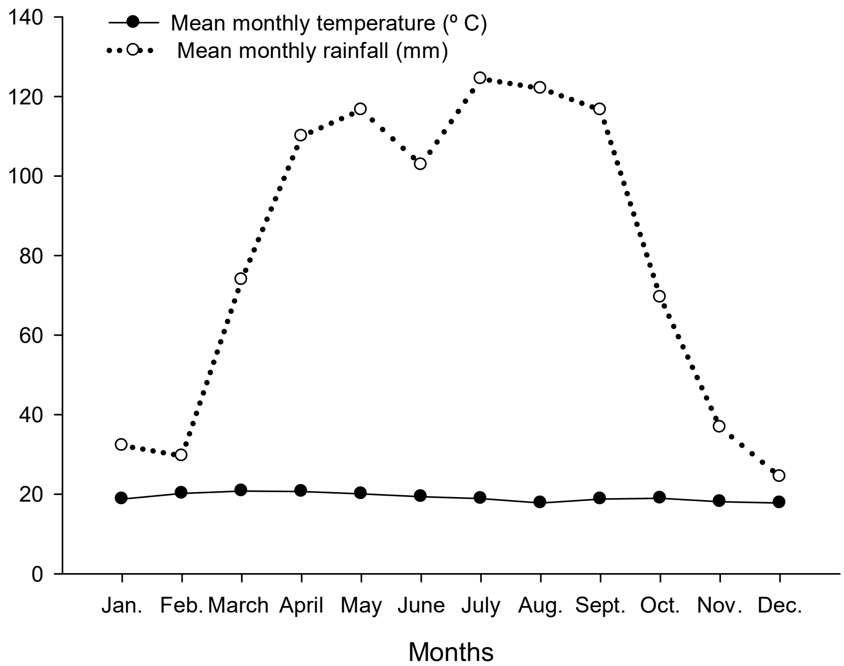

Figure 2. Mean monthly rainfall (mm) and air temperature (ºC) at the study area.

Figure 3. Land degradation status in the study area and prepared beds for sowing of seeds for the study (A); sown seeds, covered with grass clippings, to prevent them from being washed away and to protect them from birds (B).

Tree species used in the study

The list of tree/shrub species used in the field study and their uses is presented in Table 1. Six of the species belong to the family Fabaceae while the others are in Sapindaceae or Moringaceae. The seeds of *Dodonaea angustifolia*, *Vachellia nilotica*, *Vachellia seyal, Vachellia tortilis, Vachellia abyssinica, Moringa stenopetala*, used for the study, were bought from the Forestry Research Centre, in Addis Ababa.

Table 1. Species used for the field study, their respective characteristics and altitudinal ranges.

No.	**Species**	**Family**	**Tree/ shrub**	**Uses of the species**	**Altitudinal Range (m. a.s.l)**
1	*Vachellia abyssinica*	Fabaceae	Tree	Firewood, charcoal, poles, posts, tool handles, food (edible gum), medicine, fodder, bee forage, shade, nitrogen fixation, soil conservation, fence	1500-2800
2	*Vachellia nilotica*	Fabaceae	Tree	Food, fodder, apiculture, fuel, timber, fibre, gum or resin, tannin or dyestuff, medicine, reclamation of degraded land, soil improver, intercropping	600-1700
3	*Vachellia seyal*	Fabaceae	Tree	Food, Fodder, apiculture, fuel, fibre, timber, gum or resins, tannin or dyestuff, medicine, shade or shelter	1200-2100
4	*Vachellia tortilis*	Fabaceae	Tree	Food, Fodder, fuel, timber, tannin or dyestuff, erosion control, medicine, shade or shelter, nitrogen fixing	600-1900
5	*Dodonaea angustifolia*	Sapindaceae	Shrub/ tree	Fodder, Apiculture, Fuel, Timber, Medicine, soil conservation	1100-1800
6	*Moringa stenopetala*	Moringaceae	Tree	Food, Fodder, Fuel, Ornamental, Intercropping, pollution control	500-1600
7	*Maerua angolensis*	Capparaceae	Tree	Firewood, fodder (leaves), furniture, bee forage, milk curdler (leaves), flavouring of milk (smoked wood)	600-1800
8	*Senna didymobotrya*	Fabaceae	Shrub	Medicine, ornamental, Shade or shelter, soil improver	1400 - 2400

The seeds of *Maerua angolensis* and *Senna didymobotrya* were collected directly from trees in the field, their pulp removed, and then allowed to dry in the shade, after which they were kept in a plastic jar in a cold room for two months until sowing was started.

Study design and germination test

Seed germination test was performed both in the nursery and in the degraded land of the field site. In the nursery, a plastic box filled with sand was used for the seed germination test. At the field site, the soil was loosened, and the seeds were then sown and covered with thin layers of soil. For the germination test study, a randomized complete block design (RCBD), with four replications, each replications having 100 seeds were used. The seed germination test was followed between the times of 11/06/2011 to 11/09/2011 both in the field and in the nursery. The seeds sown in the nursery were watered once a day in the morning, whereas those sown in the field were not watered, with the soil there moistened by rainfall only.

For the field experimental study, the soil was loosened using a hoe, the bed was prepared, blocks and sub-blocks were formed (Figure 3A), and the seeds of each species were then sown randomly. For the field study, RCBD design, with four replicates, each replicate consisting of 100 untreated (not treated to break dormancy) seeds, were used. Each replicate has an area size of 2m * 2 m (4 m^2), and the distance between seeds were 15 cm. To prevent the seeds being washing away by heavy rainfall and to reduce the effect of bird foraging, the sown seeds in the degraded land were covered with grass clippings, with a thickness of about 1cm, for two weeks (Figure 3B).

Data collection

Daily air temperature and mean annual rainfall data were collected from the meteorological station closest to the study site (Hawassa, ca. 12 km distant). The germination data were collected weekly from 11/06/2011 to 11/09/2011. Seedling survival counts and height measurements (using a ruler) were performed weekly in the field from 11/06/2011 to 30/04/2012. Dry biomass measurement was done by uprooting seven to ten seedlings, depending on the number of surviving, for each species. The uprooted seedlings were transported to a soil laboratory and then each seedling`s root collar diameter and taproot length were measured with a calliper and ruler, respectively. Each of the seedling's root and shoots were carefully separated using a sharp knife and each seedlings part (root and shoot) was kept in a separate paper box, and then placed in a drying oven with a temperature of 60 °C for 24 hours, until they reached constant weight. Each of the oven-dried seedling's root and shoots were carefully taken out from the paper boxes and their respective weights in grams were measured using an electronic balance.

Data analysis

For each species, the germination percentages of the seeds sown at the field site and in the nursery were analysed separately. Seedling survival percentages were calculated based on the number of seedlings alive at the time of measurement divided by the total number of seeds that germinated in the field. Seedling mortality was computed from the number of seedlings that died during the particular period divided by the total number of germinated seeds.

A one-way ANOVA was used to analyse the mean shoot length, mean root length, root collar diameter, dry shoot biomass, dry root biomass and the root to shoot ratio. Fisher's least significant differences (LSD) test was used to separate means at the 0.05 significance level. We examined the relationship between the mean weekly air temperature and weekly seedling survival for each species. The SigmaPlot 13 (Systat Software, Inc., San Jose, CA, USA) software program was used for the data analysis (ANOVA and regression).

Results

Germination and survival

In the nursery, the germination of *M. stenopetala* > *V. nilotica* > *M. angolensis* > *V. tortilis* > *D. angustifolia* > *S. didymobotrya* > *V. seyal* > *V. abyssinica* (Figure 4). While, in the degraded land, the germination of *M. stenopetala* > *M. angolensis* > *V. nilotica* > *S. didymobotrya* > *V. tortilis* > *angustifolia* > *V. abyssinica* > *V. seyal* (Figure 4). The germination of the species of *V. nilotica*, *V. tortilis*, *M. stenopetala* and *D. angustifolia* in the nursery was relatively higher than their germination in the degraded land. While, the germination of *S. didymobotrya*, *M. angolensis* and *V. abyssinica* in the field was relatively higher than their germination in the field (Figure 4). The survival percentages of each plant species, as assessed on different dates during the study period, are presented in Figure 5. In the degraded land, the survival of the seedlings of *V. tortilis* > *D. angustifolia* > *V. seyal* > *V. abyssinica* > *V. nilotica* > *S.didymobotrya* > *M. angolensis* > *M. stenopetalla* (Figure 5). The survival of *V. abyssinica, V. nilotica* and *V. seyal* dropped of September, 2011 to 38.9%, 14.9% and 53.3%, respectively, as of April, 2012. Thus, the survival of *V. abysinica, V. nilotica* and *V. seyal* declined by 61.2%, 85.1%, 46.7%, respectively, over this period. The survival rates of *V. tortilis*, *D. angustifolia*, *M. angolensis*, and *S. didymobotrya* were 87.8%, 81.6%, 2.7% and 4.9%, as of April, 2012, respectively. Therefore, the survival rates of *V. tortilis*, *D. angustifolia*, *M. angolensis, S. didymobotrya* were 12.2%, 18.4%, 97.3% and 95.1%, respectively, over this period (Figure 5). The survival rate of *M. stenopetala* was 0 % as of April, 2012.

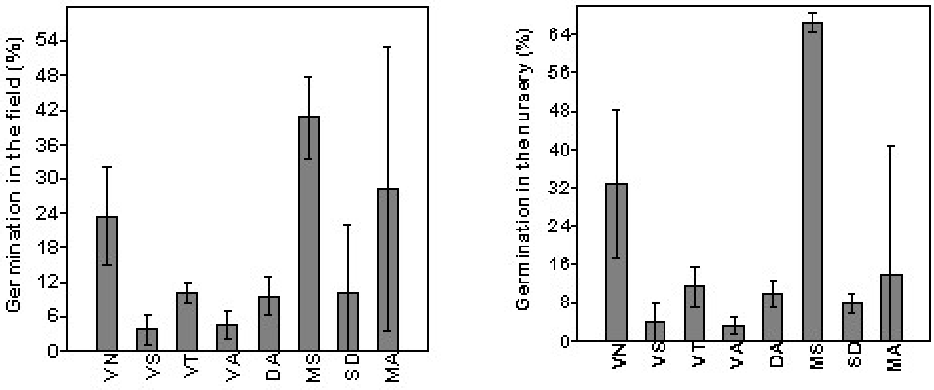

Figure 4. Germination at the field site (Left) and in the nursery (right) for each sown species with their standard error: *V. nilotica* (VN), *V. seyal* (VS), *V. tortilis* (VT), *V. abyssinica* (VA), *M. stenopetalla* (MS), *S. didymobotrya* (SD), *M. angolensis* (MA), *D. angustifolia* (DA).

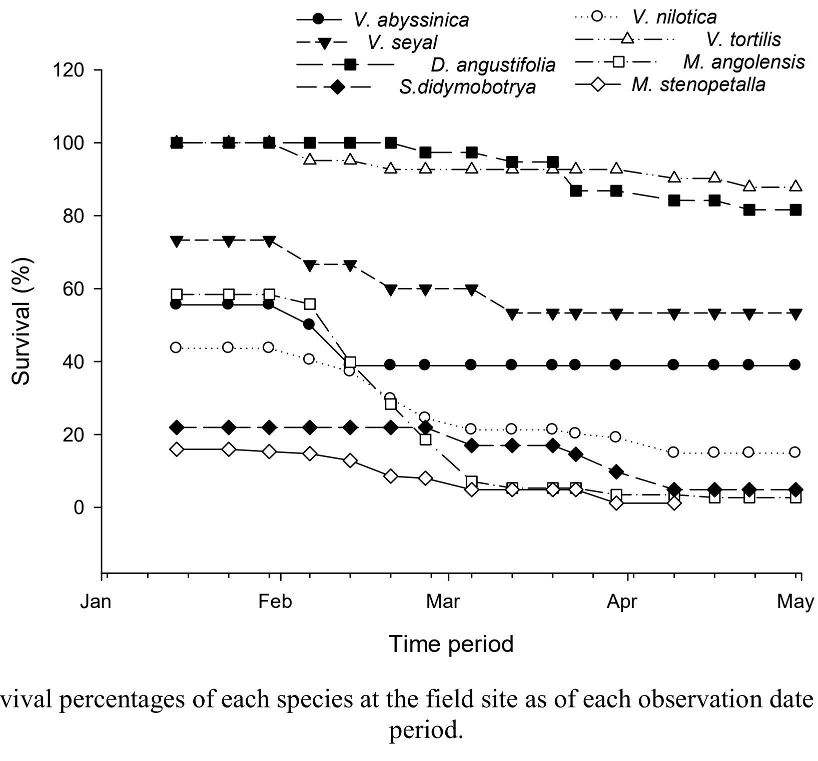

Figure 5. Survival percentages of each species at the field site as of each observation date during the study period.

The relationships between air temperature and the survival of each species at the field site at different times during the study period are shown in Figure 6. The mean weekly air temperature of the study area had negative relationships with seedling survival in the cases of *V. abyssinica* (R^2=0.35), *V. seyal (*R^2=0.51), *V. tortilis* (R^2=0.65), *D. angustifolia* (R^2=0.5) and *S. didymobotrya* (R^2=0.52). There was also a significant and positive relationship between the mean weekly air temperature and the survival of *M. stenopetala* seedlings (R^2=0.67). The relationships at the field site between dry root biomass and dry shoot biomass of each species are presented in Figure 7, showing strong positive relationships between root biomass and shoot biomass for *D. angustifolia*, *V. tortilis*, *V. seyal* and *V. nilotica.*

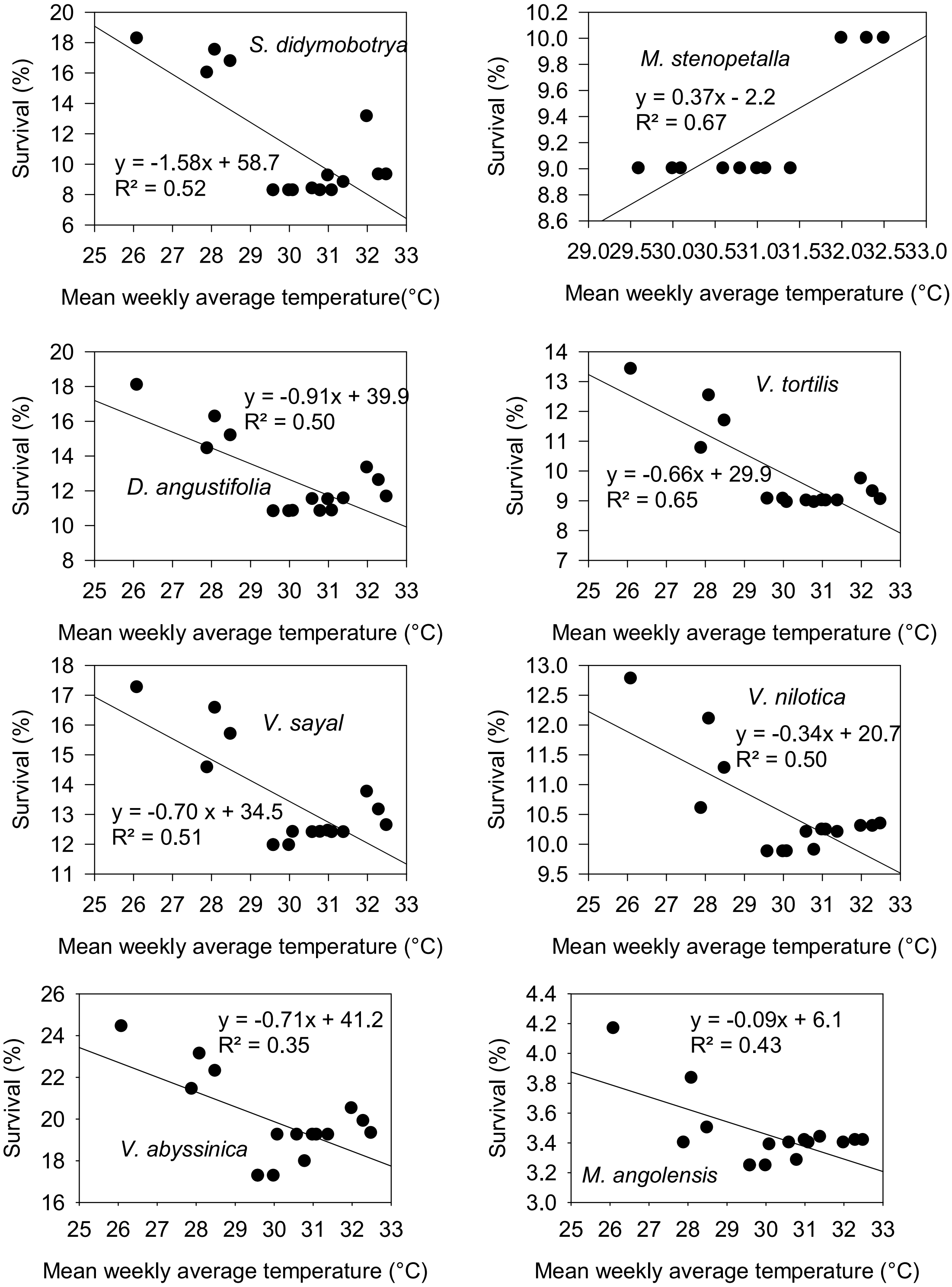

Figure 6. Correlation between mean weekly air temperature and survival percentages for each species at the field site.

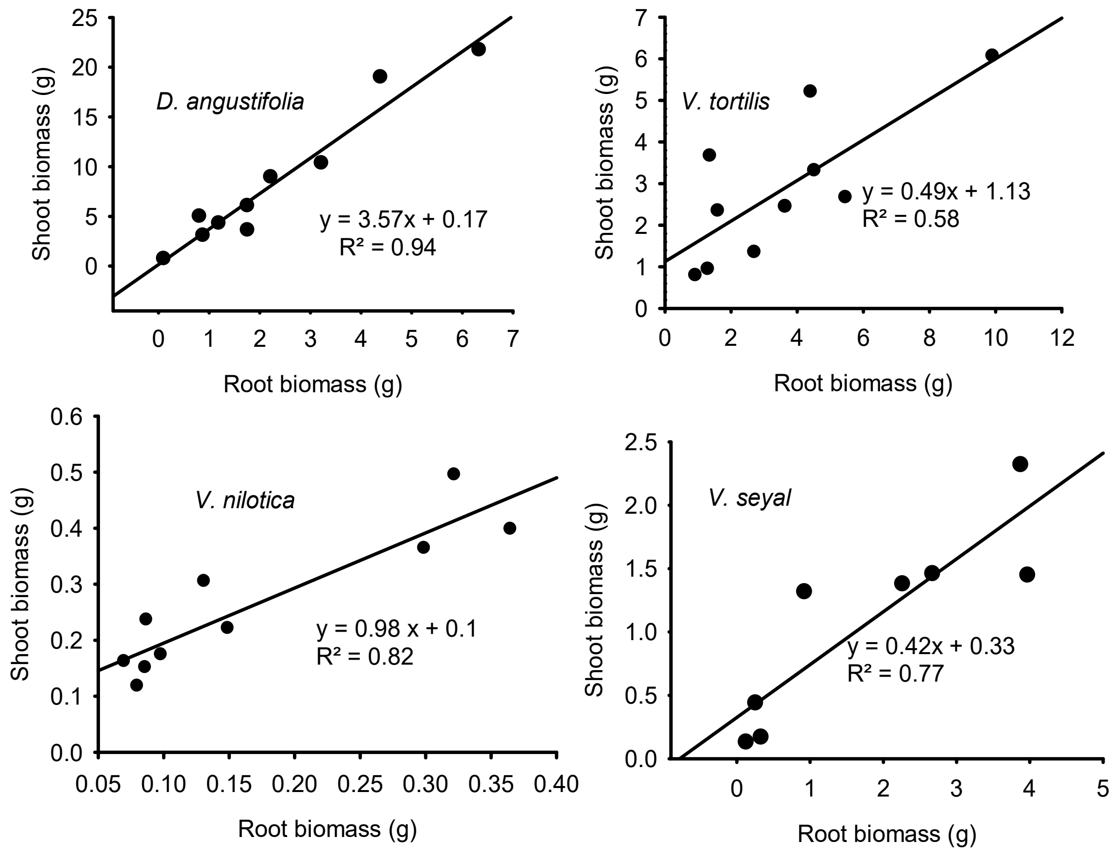

Figure 7. Correlation between dry root biomass and dry shoot biomass of the studied species at the field site.

Growth and biomass

The mean heights of each species recorded on the observation dates are presented in Figure 8. The mean heights of *V. abyssinica* > *V. seyal* > *V. tortilis* > *V. nilotica*, at the end (30/04/2012) of the field study. The mean heights of *D. angustifolia* > *S. didymobotrya* > *M. angolensis* at the end of the study period (30/04/2012). The mean daily growth rates of the species between January 14, 2012 and April 30, 2012 were 0.07 cm/day, 0.03 cm/day, 0.05 cm/day, 0.04 cm/day, 0.07 cm/day, 0.007 cm/day and 0.09 cm/day for *V. abyssinica*, *V. nilotica*, *V. seyal*, *V. tortilis*, *D. angustifolia*, *M. angolensis* and *S. didymobotrya*, respectively. The ANOVA revealed significant differences between the mean shoot lengths of the different species directly seeded at the degraded site (p=0.05, Figure 9A). The LSD test indicated that there were no significant differences in mean shoot heights between *V. tortilis* and *V. seyal*, *D. angustifolia* and *V. nilotica*. The mean taproot lengths of *D. angustifolia* < *V. nilotica* < *V. seyal* < *V. tortilis*. The ANOVA revealed significant differences in mean taproot length among the species sown at the field site (p=0.0006). The significant differences in mean tap root lengths were between *D. angustifolia* and *V. tortilis*, *D. angustifolia* and *V. seyal*, *V. tortilis* and *V. nilotica*, and *V. seyal* and *V. tortilis* (Figure 9B). The mean root-collar diameters of *D. angustifolia* > *V. tortilis* > *V. seyal* > *V. nilotica*. The ANOVA indicated significant differences among the mean root-collar diameters of the species (p=0.005) and the significant differences were between *D. angustifolia* and *V. nilotica*, *V. tortilis* and *V. nilotica*, and *V. seyal* and *V. nilotica* (Figure 9 C). The results on the mean dry root biomasses of the studied species is presented in Figure 7D. The mean dry-root biomasses of *V. tortilis* > *D. angustifolia* > *V. seyal* > *V. nilotica*. The ANOVA revealed significant differences in dry root biomass among the tested species (p=0.0027) and the significant differences were between *D. angustifolia* and *V. nilotica*, *V. tortilis* and *V. nilotica* and *V. seyal* and *V. nilotica* (Figure 7D). The mean dry-shoot biomasses of *D. angustifolia* > *V. tortilis* > *V. seyal* > *V. nilotica*.

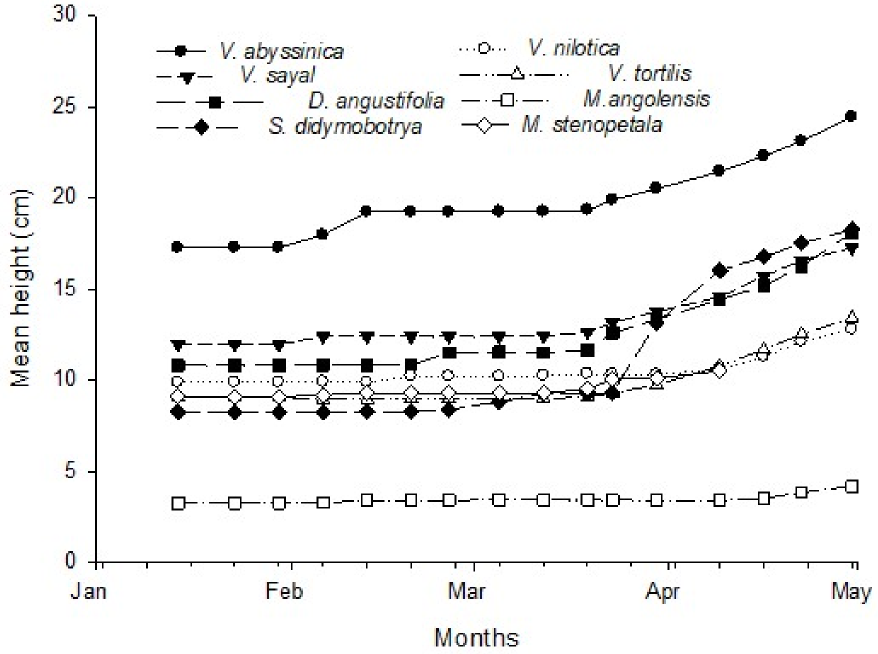

Figure 8. Means heights of each species at the field site on observation dates during the study period.

The ANOVA revealed significant differences among the dry-root biomasses of the species directly seeded in the degraded land (p=0.0001, P<0.05) and the significant differences were between *D. angustifolia* and *V. tortilis*, *D. angustifolia* and *V. seyal*, *D. angustifolia* and *V. nilotica* and *V. tortilis* and *V. nilotica* (Figure 9E). The results on the mean root to shoot ratio of the studied species in the degraded land is presented in Figure 7F. The mean dry root to shoot biomasses of *D. angustifolia* < *V. nilotica* < *V. tortilis* < *V. seyal*. The ANOVA revealed significant differences among the dry-root to shoot biomasses of the species directly seeded in the degraded land. The LSD test further indicated that the significant differences were between the species of *V. seyal* and *D. angustifolia, A. tortilis* and *D. angustifolia* (Figure 9F).

Discussion

The germination percentages of *V. nilotica*, *V. tortilis*, *M. stenopetala* and *D. angustifolia* in the nursery were higher than at the degraded site. This pattern could have been due at least in part to the regular watering of the seeds in the nursery in contrast to those at the degraded site, which had only rainfall to rely upon. Bochet et al. (2007) found that soil water availability played a major role in seed germination. This may imply that while sowing seeds for reforestation of degraded lands, if water is available for watering them could be important, in order to increase the germination percentage of the sown seeds.

The germination percentages of *S. didymobotrya* were higher in the degraded land than in the nursery. However, the survival of the seedlings in the degraded land was poor. This may suggest that higher germination of seeds at a degraded site may not always result in higher seedling survival. The lowest survival rate, of *M. stenopetala*, could have been due to attributes of the degraded land, which may have resulted in moisture stress. However, it also could have been caused by this species being planted at 1700 m a.s.l., outside of its altitudinal range of 500-1600 m a.s.l. (Tesema, 2007). *M. stenopetala* had the largest seed size, and the highest germination percentage of all the species; however it had the lowest survival. This result does not concede with the findings of St-Denis et al. (2013) and Doust et al. (2006) who stated that in general larger seeded species, had higher establishment rates in degraded lands. In the present study, *D. angustifolia* has the smallest seed size relative to other species, but it resulted in higher survival in the degraded land. This may indicate that species that have smaller seed sizes may also result in higher establishment rates when they are used for direct sowing in restoration of degraded lands.

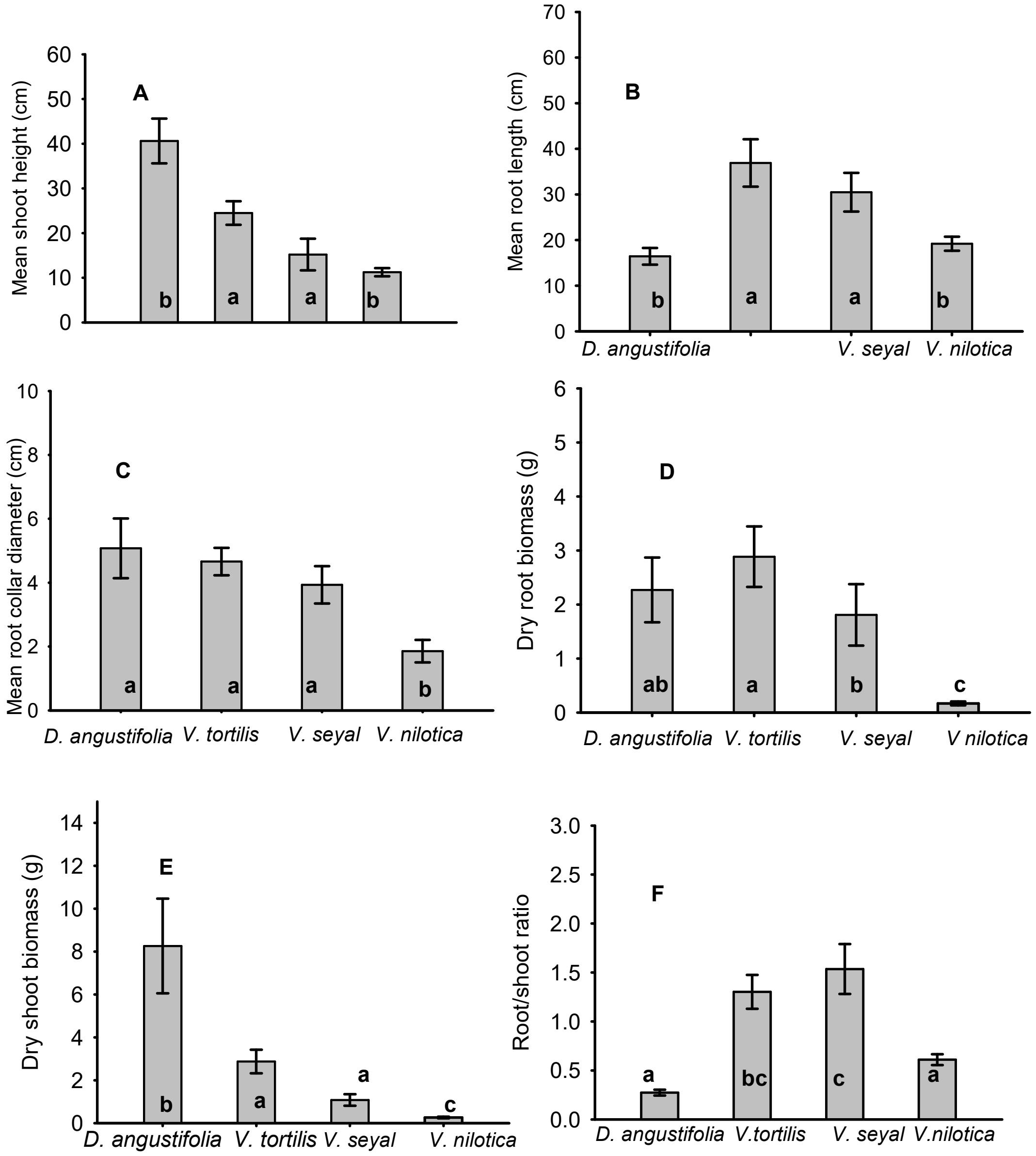

Figure 9. ANOVA results of comparisons of mean shoot heights (A); root lengths (B); root-collar diameters (C); root biomasses (D); and shoot biomass (E). Means with *the same letter are not significantly different* from each other (p=0.05).

The mortality of all the species at the degraded site increased from the rainy season (June to September) towards the dry season (October to May). This result is in agreement with Jaganathan and Liu (2015), who found that seedling mortality mainly occurred during the dry season. Lewandrowski (2016) also found that seedling survival of Triodia species decreased with water stress and high temperatures (35–40 ºC). Our results also demonstrated that air temperature and seedlings survival of most of the species were negatively correlated. Thus, as the air temperature increased, in the dry season, seedling mortality increased, which might cause loss of moisture in the soil. Indeed, other studies have indicated that air temperature has a considerable influence on seedling survival (Greenwood et al., 2015). Cardoso et al. (2015) found in their study that *Plukenetia volubilis* seedlings survival was affected by the temperature, and 35 °C significantly reduced seedling survival (52%) compared to temperatures of 25 and 30 °C.

Besides the temperature of the study area, the rainfall pattern could have also effect on the survival of the species. Muñoz-Rojas et al. (2016) in their study result indicated that temperature and rainfall patterns had a large influence on seedling emergence across five different species and suggest that seedling recruitment of the native plants may decrease in a climate scenario of increasing drought.

At the end of our study period, species such as *V. tortilis, V. seyal* and *D. angustifolia* had survival rates of above 80%, which suggests that these species may tolerate the harsh environment and be successful in establishing themselves in a degraded land through direct seeding. Bekele (2000) found very good natural regeneration of *D. angustifolia* at a rocky and highly degraded mountain site in the Wello area of Ethiopia, which could indicate the species would be able to grow on degraded land. Furthermore, Yelenik et al. (2014) indicated that *Dodonaea* species can serve as a useful initial nurse species. *V. tortilis* had on average the longest taproots at the degraded site relative to the other species. Orwa et al. (2009) stated that the long taproot and numerous lateral roots of *V. tortilis* enable it to utilize the limited soil moisture available in arid areas. Although *D. angustifolia* had on average the shortest taproot length, it had many secondary roots which might help the species to have higher survival in the degraded land.

Allocation of biomass to roots vs. shoots has long been thought to be an indicator of nutrient availability (Aikio et al., 2009). The present study results indicated that the dry root biomasses of *A. tortilis* and *A. seyal* was relatively higher than that of their dry shoot biomasses. This could be because of nutrient and moisture deficiency in the study area as a result of soil erosion problems. Studies indicated that drought stress condition increases root to shoot ratio via alteration of carbohydrate partitioning and enzymatic activity (Xu et al., 2015). Cole et al. (2011) in their study found that law root to shoot ratios in areas where there is higher nutrient availability. Palow and Oberbauer (2009) found that Inga seedlings allocated more biomass to roots and less to photosynthetic tissue when grown under low-nutrient soil. However, the dry root biomass of *D. angustifolia* species in the present study was much lower than the shoot biomass (2:8). This could be the special adaptation of the plant and this may suggest that some species that can be established in degraded lands where there are moisture and nutrient deficiency could result in higher shoot to root biomass. The present study result showed significant and positive relationships between dry-root biomass and dry-shoot biomass for *D. angustifolia, V. tortilis, V. seyal,* and *V. nilotica* (Figure 7). This result is in accord with the findings of Aerts (1991), who found a positive relationship between the root biomass and shoot biomass of the evergreen shrubs *Erica tetralix* and *Calluna vulgaris*. This suggests that higher root biomass enabled higher shoot biomass, which may mean that when choosing species for degraded land restoration via direct seeding, preference should be given to species with higher root biomass. Allaby (1998) indicated that plants with higher proportions of roots can compete more effectively for soil nutrients. Our results also showed that our study species in Fabaceae had higher survival rates than other species at the degraded site, which could be associated with the nitrogen-fixing ability of these species. Hossain et al. (2014) in their study showed that *A. xylocarpa* was successful in germinating and growing in severely degraded lands in Thailand because of the nitrogen-fixing ability of the species. Chaer et al. (2011) in their review indicated that the introduction of leguminous trees able to form symbioses with nodulating N_2-fixing bacteria and arbuscular mycorrhizal fungi constitutes an efficient strategy to accelerate soil reclamation and initiate natural succession since the symbioses give the legume species a superior capacity to grow quickly in poor substrates and to withstand the harsh conditions in degraded soils.

Study results by different Authors from different countries, such as India (Singh and Singh, 2006); Thailand (Hossain et al., 2014); Brazil (Soares and Rodrigues, 2008), indicated successful stories in degraded land rehabilitation through direct seeding of various tree and shrub species. Pandy and Prakash (2014) and Kildisheva et al. (2016) in their findings indicated the possibility of restoring degraded dry lands through direct sowing of different species In Sudan, direct seeding of *Vachellia senegal* for forest plantation was practiced on the widest scale between the years 1970 and 1992 (El Nour and El Atta, 1992). Cole et al. (2011) recommended to use direct seeding as a complimentary measure to the more intensive restoration approach of planting fast-growing and N-fixing tree. Our findings indicated that *D. angustifolia, V. tortilis, V. nilotica* and *V.seyal* can be established through direct seeding in degraded land and used for restoration projects since they have a better survival rates relative to other species used in the study. In contrast, *M. stenopetala*, *M. angolensis* and *S. didymobotrya* were not successful in establishing, and we, therefore, recommend not utilizing these species for projects using direct seeding to restore degraded land.

Acknowledgements

Funding for this study was provided by Mendel University in Brno, in the project titled ''Sustainable management of soil, forest and water resources as the pilot model for the rural development in SNNPRS, Ethiopia''. The authors would like to thank Eyasu Esheru for his assistance in data collection during the field study. The soil laboratory staffs of the SNNPR region are also acknowledged for allowing us to use their oven dry. Thanks also to Jonathan Rosenthal for editing the language of the manuscript.

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