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REVIEW ON FACTORS AFFECTING EARLY SURVIVAL OF TREE /SHRUB SEEDLINGS AND IT'S REMEDY IN RESTORATION SITES OF ETHIOPIA

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ABSTRACT

Restoration activities in degraded and/or deforested forest landscapes are common and old occurrences around the world. Tree planting is common in most forest landscape restoration initiatives. In Ethiopia, eight seedling-based landscape restoration options are identified to alleviate land degradation and its consequences. The primary purpose of this work was to review factors affecting the early survival of tree and shrub seedlings and their remedies in the restoration sites of Ethiopia. Drought and moisture stress, low soil fertility, poor seedling quality, weak species site matching, termites, livestock grazing, and seasonal frost are the basic factors that hinder the survival and growth of seedlings in the field. In situ rainwater harvesting structures, fertilizer application, the use of quality seedlings, the right species site matching, and the exclusion of livestock and grazing animals from planted seedlings are the remedies that must be employed to increase the success of tree-based restoration practices. Thus, further investigation of the factors affecting the survival of seedlings in the out-planting sites and remediation accordingly is necessary to ensure the productivity and sustainability of restoration practices in Ethiopia.

Keywords: Restoration; seedling-based; Survival; Plantation; In-situ rainwater harvesting.

INTRODUCTION

Restoration practices for degraded and/or deforested forest landscapes are common and old phenomena all over the world (Bojo & Cassells, 1995; McLain *et al*., 2019; Pistorius *et al*., 2017). There are many approaches to restoration practices, such as establishing exclosures (Birhane *et al*., 2018; Gebremedihin *et al*., 2018; Mekuria *et al*., 2018; Eshetie *et al*., 2021); area enclosures (Mebrat, 2015); planting tree seedlings (Abiyu *et al*., 2017; Pistorius *et al*., 2017); and direct seeding (Hossain *et al*., 2014). From these approaches, tree planting is common to most forest landscape restoration initiatives, in which the quality and quantity of planting material available determine the success of restoration initiatives (Vinceti *et al*., 2020). Furthermore, tree plantations through sound silvicultural management are used as one of the most effective methods capable of reversing soil, biomass, and biodiversity degradation while providing diverse socio-economic services (Lemenih, 2006).

In Ethiopia, eight seedling-based landscape restoration options are identified to alleviate forest degradation and deforestation, loss of soil fertility, overgrazing, soil erosion and sedimentation of water bodies, flooding, and landslides, as well as the impacts of climate change. These options include restoration of secondary forests, restocking of degraded natural forests, agri-silviculture and agro-silvo-pastoralism, silvo-pastoralism, woodlots and home gardens, commercial plantations for products other than industrial round wood, buffer plantations around protected areas and national forest priority areas, and tree-based buffer zones along rivers, lakes, and reservoirs (MEFCC, 2018). Additionally, private-based tree plantations are also critical for economic relief and filling the demand gap for fuelwood in the Beressa Watershed of Ethiopia (Worku *et al*., 2018).

In response to global and national forest loss and its consequences, millions of dollars are spent every year on tree-based landscape restoration activities. Nevertheless, limited after-planting management, weak species-site match, lack of time for sufficient growth of native tree species seedlings (Duguma *et al*., 2020), and scheming short-term tree planting campaigns (Wiegant *et al*., 2022) are the challenges that hamper the success of public tree growing schemes, causing poor seedling survival rates. Moreover, Preece *et al*. (2023), pointed out that lack of watering seedlings or saplings immediately prior to planting, careless planting in the wrong pit condition, and weed suppression are critical factors that affect plant survival rates in the tropics. For example, the poor survival rate is a common problem, particularly in dry areas of Ethiopia (Gebrekidan *et al*., 2020) and the Sekota district, north-eastern Amhara, Ethiopia (Eshetie *et al*., 2020). A poor seedling survival rate of less than five percent is also observed in some micro-watersheds in the Southern Nations, Nationalities, and Peoples’ Regional State (SNNPR) of Ethiopia (Wolancho, 2015). Furthermore, high variation in seedling survival rate was reported amongst the tree species planted on different planting sites due to management, biotic, and abiotic causes in Ethiopia (Derero *et al*., 2021). Additionally, post-plant management (such as weeding and creating space for new seedlings, opening the canopy, and watering in the dry season) is almost neglected in the highlands of Ethiopia (Hishe *et al*., 2020). It is also noticed that vegetation cover has declined in watersheds where restoration projects are phased out in the Tigray region of Ethiopia (Gebregergs *et al*., 2021). Moreover, problems with tree seedling survival rate are one of the significant factors that determine on farmland tree planting in north-eastern Ethiopia (Ibrahim *et al*., 2022). In contrast to this, higher seedling survival rates are observed for a few subvillage and household managed woodlots in northern Ethiopia, where more labor-intensive activities like weeding and watering are devoted to ensuring seedling survival (Ogle, 1996).

Tree plantations for restoring degraded land in Ethiopia are done with motivation, regardless of the scientific approach. For instance, in 2019, Ethiopian Prime Minister Abiy Ahmed launched his Green Legacy Initiative (GLI), which targeted the planting of 20 billion trees over the past four years. However, Fikreyesus *et al*. (2022), states that in the first season of GLI (2019), many trees were planted on rocky areas and land inappropriate to sustain them due to little local participation in planning. Post-planting watering and weeding, survival rates, and monitoring have been weak, though the average survival rates of planted seedlings were reported at 83.4 % in 2019 and 79 % in 2020 with GLIs, which might not be pragmatic (Fikreyesus *et al*., 2022).

However, there is scant information on the determining factors of the early survival of tree seedlings in the plantation sites and the applicable remedy in the case of Ethiopia. For instance, Asmelash & Rannestad (2021), shows the major challenges and strategies for successful restoration of dry evergreen afro-montane forests in Ethiopia. Therefore, this article explored the determinants of tree and shrub seedling survival in tree/shrub planting-based restoration projects and proposed remediation technologies used to improve the success of forest and landscape restoration initiatives in Ethiopia.

FACTORS AFFECTING THE EARLY SURVIVAL OF TREE SEEDLINGS IN RESTORATION SITES OF ETHIOPIA

Seedling survival is the most important variable to be considered in plantation establishment and restoration initiatives worldwide. However, successful seedling survival rates are hindered by the environment (i.e., biotic and abiotic factors) of seedlings. For example, the quality of the seedlings, the timing of planting, the preparation of the site and the fertilizer at planting, and the density of the planting are the main factors that determine the performance of the seedlings in the field (Ogle, 1996). Masaba & Etemesi (2021), hold a similar opinion when they state that successful plantation establishment is influenced by the quality of the seedlings, species-site match, and silvicultural management practices. According to. Hau & Corlett (2003), seasonal drought, belowground competition, and limited soil nutrients can significantly harm seedling growth on degraded hillside sites in Hong Kong, China. Paudel & Acharya (2018), shows that forest fire, weeds, drought, disease, and grazing are factors responsible for the mortality of seedlings in decreasing order in Nepal. Experience from Malawi indicates that destruction by livestock, attack by termites, and dry spells are the major challenges that affect the survival of seedlings (Mlamba *et al*., 2018). Research conducted in the state of Mexico indicates that low protection after plantations, rapid conversion to agricultural land, and the mismatch between the environmental requirements of the species and the characteristics of the plantation sites are the factors that lead to a low survival rate in plantation projects (Rojo, 2021). Lvarez *et al*. (2012), indicates that site condition, seasonality, and tree species selection act together on seedling performance during early establishment in the case of Veracruz, Mexico.

Similar experiences are also observed in the case of Ethiopia. For example, Mekonen & Tesfahunegn (2011), reported a low survival rate of newly planted seedlings in the Medego watershed in Tigray, northern Ethiopia, due to moisture stress, poor soil fertility, and human and animal interference. Likewise, Mahari (2014), states that drought and moisture stress, low soil fertility, termites, and grazing by livestock can significantly hinder the survival of tree seedlings on degraded lands in northern Ethiopia. A similar finding by (Eshetie *et al*., 2020) reveals that termites, water stress, and planting in infertile soil are the main factors that affect seedling survival in Sekota District, north eastern Amhara, Ethiopia. Furthermore, Tesfaye *et al*. (2020), states that seasonal frost is the major cause of tree seedling mortality, followed by drought and free grazing in the highland areas of eastern Amhara (Table 1).

Due to free livestock grazing on the common land, (Mekonnen *et al*., 2008) indicates that tree planting and establishment are hindered by grazing in the case of Wamera Seqo, Dendi district, central Ethiopia. Comparably, recent research done in the case of Sodo Guragie (SNNPR) and Meket (Amhara region) districts in Ethiopia shows that unmanaged livestock grazing and other poor livestock practices are factors in trampling tree seedlings during landscape restoration processes (Zeleke & Vidal, 2020).

Moreover, the severity of the degradation in amalgamation with other abiotic factors is also the main reason that determines the success of seedling survival and establishment in the restoration sites of Ethiopia. For instance, Gil & Tadesse (2010), reveals a poor survival rate (<10 %) of *Sesbania sesban (S. sesban), Casuarina equisetifolia (C. equisetifolia), Gravillea robusta (G. robusta), Cupressus lusitanica (C. lusitanica), Phoenix canariensis (P. canariensis), Olea europaea (O. europaea),* and *Juniperus procera (J. procera)* species in the degraded area of Wayu and Anget Mewgia kebele, in north shewa, Ethiopia, which might be associated with the degradation effect of the land and with frost problems. Similarly, Talema *et al*. (2019), states that *S. sesban* and *Leucaena leucocephala (L. leucocephala)* seedlings failed to grow on the badland even though they were treated with FYM due to the harshness of the degradation and moisture stress in the dry season. Likewie, Demisachew *et al.* (2018), states that the soil texture and bulk density properties of the restoration site play a role in determining moisture availability, which is very important for seedling survival. Moreover, Aerts *et al.* (2006), indicates that the high seedling mortality of *Olea europaea ssp. Cuspidata (O. europaea ssp. Cuspidata)* planted in spring rains is due to drought stress soon after planting. However, a significantly higher *O. europaea ssp. cuspidata* survival rate was reported under shrub cover as compared to open areas since the effect of solar radiation on soil-water evaporation was reduced by shrub canopies Aerts *et al.* (2006). Furthermore, an optimal range of shade is important for seedling growth during enrichment activities in degraded forest restoration. For example, Giday *et al*. (2019), states that O. europaea *subsp. Cuspidata* grows better in shade in the Desa'a dry afromontane forest.

Besides abiotic factors, particularly moisture stress, poor soil, and poor site condition, (Debelo & Degaga, 2017) shows that a lack of pre- and post-planting management, an unmanageable number of seedlings, weak law enforcement, and a lack of monitoring and evaluation mechanisms are the reasons for the failure of planting activity in the case of Tigray regional state, Ethiopia. Amha *et al.* (2020), noted that among the recognized silvicultural management gaps, narrow spacing has been evaluated as the main constraint by regional experts and farmers based on the experience of plantation forests in the Amhara Region.

From the perspective of the temporal pattern, different scholars highlighted the gradual decline of the survival rate of seedlings over time. For example, Amha *et al.* (2020), revealed that the survival rates of all tree and shrub species decreased considerably over time due to extended dry seasons and termite incidence in severely degraded landscapes in the west Showa Zone of Oromiya regional state, central Highlands of Ethiopia. Likewise, Gebrekidan *et al.* (2020), showed that a reduced seedling survival rate from the first to the next inventory (within four months) was observed in Tanqua, Abergelle, and Weri-Leke districts, Tigray, Ethiopia, which may be attributed to poor management (animal trampling and browsing), moisture stress, and termites. A decreased survival rate of *Prunus africana* seedlings (from the 1^{st} to the 5^{th} year after plantation) was also documented over time in the Ethiopian highlands (Abraham, 2018). Moreover, the survival rate of *Faidherbia albida (F. albida)*, *Melia azedarach (M. azedarach)*, *Moringa stenopetala (M. stenopetala)*, and *S. sesban* species has declined over the past five years in the case of Dugda Dawa District, southern Ethiopia. The better survival rate of these species is reported under soil-level bunds and half moons, while all these species planted under normal pits died after four years (Siraj *et al*., 2021). Since trees and shrubs, which are used to restore the badlands, did not or poorly survive in the dry season in the subhumid tropics (Talema *et al*., 2019). Generally, abiotic and biotic factors in combination with the degree of land degradation are the main determinants of seedling survival at the outplanting site.

Table 1: Factors affecting early survival of tree seedlings in the plantation site

No	Factors	Study area	Percent of respondents (%)	Study area	Percent of respondents (%)	Study area	Percent of respondents (%)	Study area	Percent of respondents (%)	Source
1	Drought and moisture stress	Drylands of northern Ethiopia	78.3	Sekota district, north eastern Amhara, Ethiopia	95.70	Central Rift Valley of Ethiopia	20	Dessie Zuria, highland areas of eastern Amhara	10.7	(Debelo & Degag, 2017; Eshetie *et al.*, 2020; Mahari, 2014; Tesfaye *et al.*, 2017)
2	Low soil fertility		58.6		78.49		-		-	
3	Seasonal frost		-		-		-		59.4	
4	Termites		42.5		51.91		72		-	
5	Grazing and trampling by livestock		25.2		23.66		60		8.5	
6	Plant disease		-		11.83		-		-	
7	Herbivores attack		-		5.37		-		-	
8	Weed suppression		-		3.23		-		-	
9	Lack of proper site cultivation after planting		-		58.06		-		-	
10	Using damage seedlings		-		55.91		-		-	

TECHNOLOGIES USED TO INCREASE THE SURVIVAL AND EARLY GROWTH OF TREE SEEDLINGS IN THE RESTORATION SITES OF ETHIOPIA

Technological investment in forest restoration safeguards adequate results in seedling survival and growth and gradual ecosystem recovery (Chirino *et al*., 2009). Planting on the first rains, protecting the seedlings from livestock, and planting mature and healthy seedlings are found to be the main mechanisms that the farmers used to improve the survival of trees in Malawi (Mlamba *et al.,* 2018). Digging of irrigation pits (in-situ water harvesting) and mulching are used as possible solutions to resolve drought-related seedling failures and, hence, increase the survival rate of seedlings in southern Nigeria (Höhl *et al.,* 2020). Watering, manure application, seedling protection by fencing, and planting in a small hole (30 cm diameter and 45 cm depth) show a significant effect on tree seedling survival in Kenya, while mulching, watering, and planting niches are significant for tree survival in Ethiopia (Magaju *et al*., 2020).

Furthermore, Tesfaye *et al.* (2020), states that mulching (33.5 %), hoeing and watering (24.1 %), and plant cover (21.5 %) are commonly practiced for frost management in the highlands of northeastern Ethiopia. Likewise, (Mekonnen *et al*., 2017) indicates that household size, access to a reliable water supply, and management factors (including fencing and watering planted seedlings, mulching during dry periods, clean spot weeding, and applying organic fertilizer) significantly improve the survival and growth of tree lucerne in planted sites in the Ethiopian highlands. The major technologies applied to increase the survival rate of tree and shrub seedlings at out planting sites in Ethiopia are discussed in detail below.

In-Situ Rain Water Harvesting

In situ rainwater harvesting is applied to in-field soil and vegetation management practices to increase infiltration and reduce runoff and evaporation (Piemontese *et al.*, 2020). The survival and growth of seedlings are significantly influenced by the season, indicating the importance of moisture (Bharali *et al.,* 2012). For instance, poor seedling survival was observed in the Tuba micro-watershed due to late planting in reference to the rainy season and related to land degradation problems since the degraded land has poor soil fertility and water holding capacity in the case of the SNNPR state of Ethiopia (Wolancho, 2015).

Thus, employing in-situ rainwater harvesting strategies is an important way of enabling favorable conditions for tree seedling survival in moisture-stress areas by conserving the moisture of the area (Demisachew *et al*., 2018; Wubalem *et al*., 2012). For example, Mekonen & Tesfahunegn (2011), states that the implementation of soil and water conservation physical structures increased the survival rate of seedlings on community and private land in the Medego watershed in Tigray, northern Ethiopia. Moreover, research done at Gara Adulala, Oromia, Ethiopia (Wubalem *et al*., 2012) reveals that the survival of seedlings is higher in semicircular bunds and contour bench terraces of in situ water harvesting structures as compared to eyebrow terraces and infiltration pits. In contrast to this, Siyum *et al*. (2019), states that moisture harvesting systems, particularly the eyebrow basin, are considered the most appropriate planting pit in the case of degraded lands in southern Tigray. Cheneke *et al*. (2021), shares a similar opinion when they state that the moisture conservation structures, mainly trenches, are considered the most appropriate planting pit for degraded area closure in Babille district, Ethiopia. For example, Cheneke *et al.* (2021), states that the mean survival of seedlings planted in trenches (65 %) is higher than in normal pits (57 %), and soil bunds (56 %), four years after establishment. Disparate to this, Mamo *et al.* (2016), shows that the mean survival of seedlings planted in half-moons (80 %) is higher than in normal pits (73.33 %) and trenches (60 %) three years after establishment in the case of Hawi Gudina district, west Hararghe Zone, Ethiopia. Research done by Bayen *et al*. (2020), indicates that Senegalia species are suitable for planting in degraded land in semi-arid areas in half-moon because the soil moisture content significantly increased from the top to the bottom than in standard plantations and zaı¨ in the case of Burkina Faso. According to Siraj *et al.* (2021), half-moon and soil-level bund in-situ water harvesting structures are also specified as a potential approach for alternative forest and soil restoration in arid areas of Ethiopia. From a slope perspective, Demisachew *et al.* (2018), states that almost all in-situ structures play a crucial role on flat land rather than in the middle and upper parts (Table 2).

Besides improving the survival rate of seedlings, a rainwater harvesting structure increases the biomass production and growth of newly planted tree seedlings. For instance, Alem *et al*., (2020) states that there is a significant increase in the mean dbh, height, and total biomass of *Acacia saligna (A. saligna)* and *C. equisetifolia* planted in a trench relative to a normal pit in the case of restoring degraded land in southern Ethiopia. Generally, in-situ rainwater harvesting micro-basin structures can mitigate the effect of dry spell shocks on tree seedling performance and land cover rehabilitation (Derib *et al*., 2009).

Table 2: Impact of in-situ rain water harvesting technologies on survival rate of seedlings in the case of Ethiopia

No	**In-situ rain water harvesting technologies (IRWHT)**	**Mean survival rate of tree seedlings under different factors**					**Source**
		Factor/s	Slope class (0-5)	Slope class (6-10)	Slope class (>10)	-	
1.	Infiltration pits	IRWHT & Slope	66.53^{a}	46.13^{a}	28.80^{a}	-	(Demisachew *et al.*, 2018)
	Half-moon		66.53^{a}	42.60^{ab}	25.67^{a}	-	
	Level soil bund embankment		55.47^{b}	41.80^{b}	20.40^{b}		
		IRWHT & Time	Year I	Year II	Year III	Year IV	(Mamo *et al.*, 2016)
2.	Half-moon		93.33^{a}	86.67^{a}	80^{a}	-	
	Normal pit		80^{a}	73.33^{a}	73.33^{a}	-	
	Trench		80^{a}	80^{a}	60^{a}	-	
3	Trench	IRWHT & Time	63.13^{a}	58.48^{a}	57.13	56.73	(Chenek *et al.*, 2021)
	Normal Pit		57.93^{b}	53.00^{b}	58.28	56.4	
	Soil level bund		57.13^{b}	52.40^{b}	57.93	56	
		IRWHT & Time	1st survival rate	2nd survival rate	3rd survival rate	-	(Siyum *et al.*, 2019)
4	Eyebrow Basins		91.67^{a}	63.89^{a}	63.89^{a}	-	
	Micro trenches		97.22^{a}	63.92^{a}	63.89^{a}	-	
	Improved Pits		88.89^{a}	55.56^{a}	55.56^{a}	-	
	Normal Pit		91.67^{a}	41.67^{a}	33.33^{a}	-	
		IRWHT & Plant Species as a factor	*F. albida*	*M. azedarach*	*M. stenopetala*	*S. sesban*	(Siraj *et al.*, 2021)
5	Soil level Bund		58.67^{a}	77.87^{a}	38.62^{a}	28.61^{a}	
	Half moon		55.00^{a}	77.12^{a}	70.30^{a}	10.01^{a}	
	Trench		40.00^{a}	40.53^{b}	40.11^{a}	23.33^{a}	
	Control (Normal pit)		0.00	0.00	0.00	0.00	
6.		IRWHT, Time &	*G. robusta*	*Eucalyptus*	*O. europaea*	*J. procera*	Siyum *et al.*, 2019)

		Plant Species		*globulus (E. Globulus)*			
	Eyebrow Basin	1 year	100	100	77.78	88.89	
		2 years	100^{a}	100	11.11	44.43	
		3year	100^{a}	100	11.11	44.44	
	Micro trenches	1 year	100	100	88.89	100	
		2 year	55.56^{b}	66.67	33.44	100	
		3 year	55.56^{b}	66.67	33.33	100	
	Improved Pits	1 year	88.89	77.78	88.89	100	
		2 year	44.44^{b}	44.45	55.56	77.77	
		3 year	44.44^{b}	44.45	55.56	77.78	
	Normal Pit	1 year	100	100	77.78	88.89	
		2 year	55.55^{b}	44.44	11.11	55.55	
		3 year	55.56^{b}	11.11	11.11	55.56	
7	Semi-circular bunds	Mean survival rate (%) only by IRWHT factor					(Wubalem *et al*., 2012)
		81.7	-	-	-	-	
	Contour-bench terraces	76.7	-	-	-	-	
	Eyebrow terraces	40	-	-	-	-	
	Infiltration pits	5	-	-	-	-	
8	trench	65^{a}	-	-	-	-	(Assefa *et al*., 2021)
	normal pit	57^{a}	-	-	-	-	
	soil bund	56^{a}	-	-	-	-	
9	Backyard	30.45^{a}	-	-	-	-	(Mekonnen *et al*., 2017)
	Outfield-terraces	11.19^{b}					
	Outfield-Irrigated land	9.42^{b}					

Notice: 2nd survival rate measured 5-month letters after 1st survival rate and 3rd survival rate was measured 7 months letters after 2nd survival rate. Similar letters in the column show not a significant difference and different letters indicate significant differences.

Soil Fertility Improvement

Fertilization treatments are fundamental during the early stages of forest plantation development to enrich the soil of the plantation site with essential nutrients that may enhance the survival and growth of tree seedlings (Jaquetti & Gonçalves, 2021). Asmelash *et al*. (2016), reveals that the inoculation of arbuscular mycorrhizal (AM) fungi can potentially improve the restoration success of degraded land by improving plants' tolerance to biotic and abiotic stresses and hence significantly increasing tree and shrub seedling survival, establishment, and growth. A similar finding by Masazumi *et al*. (2019), indicates that using biochar for the seedlings in the plantation site enhances symbiosis with AM fungi under water deficit, and this method might be efficient for the restoration of degraded dry lands. Furthermore, Abebe *et al*. (2020), indicates that soils from the remnant church forests, particularly from Croton macrostachyus, can promote the growth and survival of *O. europaea* and *Albizia gummifera (A. gummifera)* seedlings in degraded lands because this soil serves as a potential source of soil microbiome. However, Asmelash *et al*. (2016), states that AMF inoculation has no statistically significant effect on the survival rate of J. procera seedlings in the case of Chancho, central Ethiopia.

In the absence of fertilizers to be used on the plantation sites, nutrient-loaded tree seedlings can be used to offset early field fertilization needs at forest reclamation sites (Schott *et al*., 2016). Seedlings grown on potting mixtures amended with soil-applied fertilizer have a lower probability of plant mortality compared to those without fertilizer (Sileshi & Akinnifesi, 2007). Likewise, Mulugeta (2014), shows that there is a significantly higher survival rate and other seedling quality indicators for *Cordia africana (C. africana)* and *A. gummifera* trees under a 5:4:1 ratio of forest soil, compost, and sand, respectively. From the sources of fertilizer, cow dung is the preferred organic manure for raising trees and shrubs to make nutrients available for optimal growth of seedlings (Han *et al.,* 2016).

Regarding the impacts of fertilizer application as post-plantation management practices to improve the survival rates of woody plant species, Tizazu et al. (2022) shows that the highest survival rate is observed for *C. africana, O. europaea,* and *C. lusitanica* tree species with FYM+Urea application than FYM, Urea, and Contro in the case of Sutte microwatershed, in Mirab Abaya district, south Ethiopia. While the highest survival rate is observed for *G. robusta* species with FYM application than FYM+Urea, Urea, and Contro. Comparably, Talema *et al.* (2019), reported that *Syzygium guineense* and *G. robusta* species show significantly higher survival rates with FYM treatment than without, whereas manure treatment did not show any significant effect on the survival rate of *Jatropha curcas* species.

Tree Seedling Quality and Factors Affecting Its Quality Production in Ethiopia

Seedlings are the basis for many terrestrial ecosystem restoration methods worldwide. Seedling quality is an important component of any successful forest and other landscape restoration program (Abate *et al*., 2018; Grossnickle & MacDonald, 2018). Thus, maintaining seedling quality is a critical and investment-intensive issue for implementing global forest and landscape restoration programs (Haase & Davis, 2017). The lack of seedling adaptation to harsh site conditions and the limited supply of high-quality native seedlings are the main technical obstacles to regeneration success and productivity (Höhl *et al*., 2020). According to Tesfaye *et al.* (2020), seedling quality indicators such as mean shoot length, root collar diameter, shoot, and root dry mass differ among nursery ownership types and have a significant effect on survival and early growth in the case of the central Gondar Zone, Ethiopia. Dedefo *et al*. (2017), states that lack of sufficient material and germplasm input and the use of seeds of low or unknown quality are the problems that challenge tree seedling production and lead to underperformance of seedlings in the Oromia region of Ethiopia.

A similar opinion was shared by Nef (2019), when they state that a lack of genetic quality in seeds may lead to a failure of seedling production, influencing the success of restoration initiatives. Furthermore, poor access to seeds of some species, poor availability of water sources during the dry season, lack of skill, and poor inherent soil properties of the dominant soil type are factors that result in poor quality seedlings (Amha *et al.*, 2013). Because optimal irrigation and fertilization rates should be considered together to produce high-quality seedlings with desirable seedling attributes for field performance (Shi *et al*., 2019).

The intrinsic properties of the seedling, such as species identity and initial seedling size, may be the key factors in determining the seedling survival rate in the field (Shen *et al*., 2020). Gardiner *et al*. (2019), indicates that planting seedlings between 25 and 35 cm tall will increase the early survival and growth rate of the seedlings in restoration projects in degraded areas. Charles *et al*. (2018), also pointed out that planting larger seedlings may improve seedling growth and could be used as a strategy to increase seedling survival. Since seedlings from populations with longer roots, larger seeds, and earlier emergence are significantly more likely to survive the first growing season (Leger *et al*., 2019). Macera *et al*. (2017), also shows that seed mass is a functional trait that can predict the probability of the establishment of individual trees during forest restoration because seed mass can positively influence the probability of seedling survival.

Species Site Match

Species-site match is an important aspect of restoration efforts to ensure the success of a program (Parlucha *et al*., 2017; Safa *et al*., 2008). This is due to the need for the selected tree species to be provided with a suitable environment that will allow them to grow (Ho *et al*., 2016). Derero *et al.* (2020), states that there is a significant effect of species and niche on growth differences of the species *C. africana, G. robusta, Jacaranda mimosifolia, L. leucocephala, M. stenopetala, and S. sesban*, which are common to semi-arid and sub-humid agro-ecologies in Ethiopia. From these species, *G. robusta* and *S. sesban* attained their highest mean height in the subhumid homesteads and their lowest mean height in the semi-arid boundary plantings. While the highest mean dbh was attained by *M. stenopetala* in sub-humid homesteads.

Local and regional environmental variation influences seedling survival and growth (Román-Dañobeytia *et al*., 2012). For example, Kasaye *et al*. (2020), states that *Senegalia senegal* (*S. senegal*) and *M. stenopetala, S. senegal*, and *A. saligna* could be used to restore degraded land and support ongoing land rehabilitation programs for lowland, midland, and highland altitudes, respectively, in northern Ethiopia and similar agro-climatic zones. A similar opinion was shared by Alebachew *et al*. (2015), when they state that *S. sesban* and *A. saligna* can be selected as pioneer species to rehabilitate degraded lands on a cool, humid plateaux where it is favorable for the growth of many mid- and high-land plant species. Similarly, Amha *et al*. (2020), revealed that *S. sesban* and *A. saligna* are the outstanding species with the best growth and survival rates, and hence, they can be used as entry species to rehabilitate degraded lands in the central highlands of Ethiopia and other areas with similar agro-ecological conditions. Boissière *et al*. (2020), states that bamboo species would be an important component in land restoration efforts due to their fast-growing nature and extensive root and rhizome systems in the case of Benishangul-Gumuz Regional State, Ethiopia. According to Tesfaye *et al*. (2014), *Hagenia abyssinica (H. abyssinica)* and *G. robusta* tree species can be used for soil rehabilitation as they showed the highest survival rate in the Ethiopian central highlands. Furthermore, Gil & Tadesse (2010) reveals that *E. globulus* (90 % survival rate) is one more potential species to restore degraded lands than *S. sesban, C. equisetifolia, G. robusta, C. lusitanica, P. canariensis, O. europaea,* and *J. procera*

(< 10 % survival rate) in the case of the degraded areas of Wayu and Anget Mewgia kebele, in north Shewa. Contradictory to this, Wolancho (2015), states that maintaining the Eucalyptus species on degraded communal land at the Garato micro-watershed is not suitable for restoration.

Table 3: The survival rate of tree/shrub species in different restoration projects in different parts of Ethiopia

No	Species name	The survival rate in %	Place of the plantation	Source
1	*G. robusta*	55.5	Tanqua Abergelle and Weri-Leke Districts, Tigray, Ethiopia	(Gebrekidan *et al.*, 2020)
2	*V. lehay*	74		
3	*Eucalyptus camaldulensis*	61		
4	*M. stenopetala*	64		
5	*C. equistofilia*	55.4		
6	*Z. spina-christi*	51.4		
7	*P. acculata*	50.4		
8	*V. tortilis*	51.9		
9	*L. leucocephala*	48.2		
10	*M. stenopetala*	41.4		
11	*O. europaea*	34.77	Lake Haramaya watershed, eastern Ethiopia	(Sorecha, 2017)
12	*H. abysinica*	48.03		
13	*A. gummifera*	4	West Showa zone of Oromiya Regional State, central highlands of Ethiopia	(Amha *et al.*, 2020)
14	*O. europaea subsp. cuspidata*	51		
15	*S. sesban*	80		
16	*A. saligna*	71		
17	*A. decurrens*	20		
18	*V. tortilis*	87.8	Kajimma Umbullo Kebele, Sidama Zone, Southern Nations, Nationalities and People Regional state of Ethiopia.	(Alem & Habrova, 2019)
19	*D. angustifolia*	81.6		
20	*V. seyal*	53.3		
21	*Vachellia abyssinica*	38.9		
22	*Vachellia nilotica*	14.9		
23	*Senna didymobotrya*	4.9		
24	*Maerua angolensis*	2.7		
25	*M. stenopetala*	0		

Sorecha (2017), states that poor growth and survival rates were observed in *O. europaea* tree species compared to *H. abysinica* in the degraded lake of the Haramaya rivershed, Ethiopia. Amha *et al*. (2020), also reveals that the integration of *S. sesban* and *A. saligna* with a native species plantation of *C. africana*, *J. procera*, *Millettia ferruginea*, and *O. europaea subsp. cuspidata* improves their growth and survival rates. The experience of the Tanqua Abergelle and Weri-Leke districts, Tigray, Ethiopia, showed higher survival rates

(>80 %) for the species *Ziziphus spina-christi (Z. spina-christi)*, *Vachellia tortilis (V. tortilis)*, and *Parkinsonia aculeata* (*P. aculeata*) planted in the degraded site (see Table 3). Moreover, *Dodonaea angustifolia (D. angustifolia)* (low land), *V. tortilis* (low land), and *Vachellia seyal (V. seyal)* (low land and mid land) woody species are successful in growing in the degraded area of southern Ethiopia (Alem & Habrova, 2019). When species survival rate is more than 80 %, there is no need for replacement planting, while for survival rate below 80 %, replacement planting is needed to improve the stock and proper land use (World vision, 2020).

In harshly degraded sites where the survival rate of native tree and shrub species is poor, using early successional species such as locally adapted and selected grasses before the plantation of trees and shrubs is effective (Talema *et al*., 2019). Whenever the restoration project is started with exotic foster or nurse trees and shrubs, gradual replacement of exotic plant species with native species is recommended to maintain the biodiversity of the area (Pistorius *et al*., 2017). Furthermore, evaluating the land potential for individual species and assigning these species based on their land requirements should be done before planting to increase the survival rate of trees (Teka & Welday, 2017).

CONCLUSIONS AND RECOMMENDATIONS

Drought and moisture stress, low soil fertility, poor seedling quality, poor species site matching, termites, and livestock grazing are the basic factors that hinder seedling survival in out-planting sites. A better survival rate of seedlings can be achieved with suitable in situ rainwater conservation measures, the application of fertilizer, the use of quality seedlings, the introduction of niche-compatible tree species, the application of appropriate silivicultural practices, and controlled free grazing systems. Overall, detrimental factors that may hinder seedling growth and its management approach should be identified and planned to be implemented prior to the onset of seedling planting. Based on this review, the following are recommended for researchers to conduct further research and policymakers to design tree-based restoration projects that allow the restored system to be productive and sustainable:

*For researchers***:**

- ✓ More research should be done on factors affecting the survival of tree and shrub seedlings in restoration projects across the country because the available findings are not sufficient.
- ✓ More research should be done on in situ rainwater harvesting technology per soil, characteristics of the site, agroecology, and species type because these factors together would determine the amount of water or moisture capacity to be conserved.
- ✓

For policy makers:

- ✓ Tree-based restoration projects should be implemented based on science and the principles of restoration to enable the restored system to be productive and sustainable.

DATA AVAILABILITY

The data supporting this review that has been cited is from previously reported studies and datasets.

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CONFLICT OF INTEREST

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this document.

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