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Early nursery performance of Acacia Seyal from different provenances in in Hawassa Zuria District, Sidama Region, Ethiopia

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ABSTRACT

Understanding variations in seed traits and seedling vigor in various populations of a given species is vital. The main objective of this study was to evaluate seedling growth performance of Acacia seyal tree provenances and determine the best-performing provenances. Seeds were collected from (Shaba, Halaba, Loka Abaya, Arsi Negele, Megabi, Meraro, Dangla, Negele Borana, Metema, Chiro, Debrebirhan, Arbaminch, and Ziway) areas. One hundred polyethylene pots, having a 10 cm height and an 8 cm diameter for each provenance, were filled with a 2:1:1 ratio of local soil, forest soil, and sand composition. A Completely Randomized Design (CRD), 5×4 polyethylene pots in 4 replications of 20 polyethylene pots, was used, and the pots were sown at the Hawassa Zuria nursery site. Germination, seedling height, collar diameter, number of leaf pairs, dry mass of fresh leaves, roots, and stems, and oven-dried leaves, stems, and roots were brought to 72°C for 48 hours. The collected data were subjected to Analysis of Variance (ANOVA) at $p < 0.05$. Results of the experiment revealed that Acacia seyal varied significantly ($p < 0.05$) among the provenances with respect to seedling height, root length, number of leaf pairs, and RCD. The seedling height ranged from 22.4 cm to 10.3 cm, with the highest mean height recorded from the Loka Abaya provenance (22.4 cm); Arbaminch (10.3 cm) had the least mean height. In terms of fresh and dry-weight biomass, statistically higher leaf, branch, and root dry-weight biomasses were recorded from the Megabi, Loka Abaya, and Halaba provenances, respectively. The provenances from Loka Abaya, Negele Borana, and Dangla had good adaptation potential.

Contribution/Originality: This study is one of the very few studies in Ethiopia that investigated and proved a response to planting sources, or the provenance test, of Acacia seyal tree seeds under the nursery management system in central Ethiopia, where tree-seed regeneration and survival have challenged local seedling-raising farmers, institutes, and cooperatives under several conditions.

1. INTRODUCTION

The genus Acacia includes about 800 species widely distributed in the Africa semi-arid Zone. They are abundant in savannah and arid regions of Australia, Africa, India and the Americas. Acacia seyal belongs to the genus Acacia, which is one of the largest genera within the family Mimosaceae [1]. Acacia seyal is found in both Western and Eastern Africa on the Arabian Peninsula; while variety fistula is found in the Eastern parts of Africa, indicating that variety seyal is native to many African countries [2]. According to Elbadawi, et al. [3], Acacia seyal is native to Egypt, Eritrea, Ethiopia, Ghana, Iran, Israel, Kenya, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Saudi Arabia, Senegal, Sudan, Syrian Arab Republic, Tanzania, Uganda, Yemen, Republic of, Zambia, Zimbabwe. It is a small to medium tree attains a maximum height of up to 17 m high and 60 cm in diameter, occurs in areas with 500-1200 mm rain year -1 and a distinct dry season and growing up to 2000 m in the upper elevation limit range [4]. Acacia seyal is grown in different growing niches like home gardens, farmlands, and woodlands [5]. In most parts of Ethiopia, the most common practice is like integrating agricultural crops with the tree is a common practice [6].

Acacia seyal is predominantly a tree of the cracking clay soil found in large, almost pure stands or mixed with Acacia senegal and Balanites aegyptiaca under rainfall of 250 to 1000 mm, under low rainfall on water- receiving sites and depressions. Confined in the Flood Region to low elevation intermittently flooded by rain [7]. Acacia seyal is attributed to being a multi-purpose tree that produces excellent fuel wood, quality gum production, charcoal, animal fodder, improve soil fertility, vital for the paper industry and in turn helps to alleviate poverty and enhance rural development [3, 8, 9]. Dryland areas can benefit most from tree species that are moisture-stress tolerant, multi-purpose, fast-growing, nitrogen-fixing, and that produce many seeds, provide useful wood products, break the wind, increase soil and water conservation, provide shade and produce large amounts of biomass for animal fodder. The great promise of Acacias forages its suitability for dry regions, where pasture grows poorly or only seasonally; the leaves, pods, or young shoots provide mainly the main browse for animals and have fair to excellent palatability for domestic livestock such as cattle, sheep, goat, donkey and camel. Most Acacias grow vigorously, coppice readily and withstand heavy browsing. The leafy branches can be cut for fodder within the season without significant damage to the tree [10]. Different scholars also documented that farmers manage woody species including A. seyal within their home gardens and on their farms to derive a range of benefits such as firewood, fuelwood, charcoal, and fodder [11].

Provenance tests are typically established with commercially important species [12]. A provenance trial, where many sources of a promising species are tested, is an essential tool to clarify the extent of variation within a species [13]. Provenance research is claimed to be among the most important contributions of forestry to biological sciences [12]. However, provenance research has received little attention in Ethiopia despite its importance in afforestation and reforestation programs. According to Langlet [14], provenance trials expose the ecological variability within species, the relationship between this variability and the environment, and the responses of different populations when transferred to a new environment.

Better understanding of variations in seed traits and seedling vigor in various populations of a given species is vital for appropriate nursery and tree planting technology. Survival and performance, measured in terms of height and diameter, are indicators of the adaptive potential of provenance species [15]. A provenance refers to a particular population of trees that come from a specific geographical location. Adaptive potential is the sum of the changes due to genetic adaptation and phenotypic plasticity [16]. Provenance testing is an expensive long-term exercise, and so comprehensive trials are only possible for the most valuable forestry species. Selection of the best Acacia seyal provenance is a fundamental input for the plantation program campaign set by the Ethiopian government and scale-up program of the best-performing species for a given site and purpose. The objective of this experiment was to evaluate different provenances of Acacia seyal in terms of seedling performance to identify appropriate seed sources for scale-up in a wider area.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

The study area is found at Hawassa Zuria district Jara - Hinessa forestry nursery site, which is about 285 km south of Addis Ababa and 10 km away from southeast Hawassa town, which is the capital city of Sidama Region, with an altitude of 1757 m.a.s.l. Geographically, the experimental site is situated 07^{0} 03"N latitude to 38^{0} 28" E longitude. The Climate of the experimental site is represented by the Hawassa town meteorological station located 12 km away from the Nursery site. The average annual rain fall 961 mm and the average temperature of the area is 19.60 c. It is bounded by Oromiya in the north and west, Lake Hawassa in the east and Tula Sub-city of Hawassa Town Administration and Shebedino Woreda of Sidama Region in the southeast and Boricha Woreda of the Sidama Region in the south. From rural 23 Kebeles of the district, 18 are found in Kola and 5 are in woina dega agro- ecological region, respectively.

2.2. Vegetation and Land Use System

The dominant vegetation types in the study area are woodland, wooded grassland, forest land with Acacia *brevispica* Harms, *Euphorbia tirucalli* L, *Dodonea angustifolia L*, *Rhus natalensis* Krauss, *Balanites aegyptiaca* (L.) Del. *Dichrostachys cinerea* (L.) Wight & Arn, *Acacia tortlis subsp. spirocarpa (*Hochst. ex A.Rich.) *Acacia lahai* Steud. & Hochst. *Acacia seyal* Delile ex Benth and *Euclea schimperi* (A.DC.) Dandy was one of the common woody species in the study area. The main farming systems are dominated by mixed crop-livestock systems with mainly traditional homegarden agroforestry practices as the major land use practices. The dominant plant species are *Ensete ventricosum*, *Catha edulis*, *Capsicum annuum*, *Saccharum officinarum* were perennial crops in the system primarily cultivated for home consumption while *Zea mays*, *Phaseolus vulgaris*, *Sorghum bicolor* are some of cultivated annual crops for income sources and home consumption.

There are two cropping seasons in the study area, i.e., Belg (Short rainy season), which runs from March to May and Meher (main rainy season), which occurs in the months from June to September. Belg rains are mainly used for land preparation and planting long-cycle crops such as maize. The Meher rains are used for planting potato, green pepper, haricot bean, sweet potato and to some extent teff. The main livestock species are cattle, goats, sheep and poultry.

The farming system of the study area generally depends on a mixed farming system. Both crop production and animal husbandry were commonly practiced. Major cash crops are maize, haricot bean, potato, and green pepper. The main crops grown during the two cropping seasons are maize, haricot bean, potato, green pepper, sweet potato, and in some parts sugar cane and enset.

2.3. Experimental Design

Seeds were sown in the polyethylene bags. Following the seed collection and treatment, 100 polyethylene pots having a height of 10 cm and a diameter of 8 cm for each provenance were filled with a 2:1:1 ratio of local, forest soil and sand composition for raising the seedlings.

Accordingly, using a Complete Randomized Design (CRD), 5 × 4 polyethylene pots in 4 replications of 20 polyethylene pots for each provenance were designed in the nursery. Seedling survival was supervised until two weeks and the dead seedlings were replaced with normal seedlings. Watering and weeding were done regularly (morning and evening) when it was necessary.

Finally, data on early survival and mortality rate as well as growth performance of seedlings were also collected four months after the completion of transplanting in the polyethylene pots.

2.4. Geographic Location of the Provenances

The seeds of *Acacia seyal* have been collected from representative stands in thirteen different areas (Table 1). Seeds were collected from healthy, vigorous trees (good phenotype); collection from mature dominant or co-dominant; overly mature trees should be avoided. Seeds should not be collected from isolated trees of cross-pollinating species or border trees because of risk of self-pollination (i.e., low productivity and viability). Collection from a certain minimum number of trees, at a prescribed minimum distance. In other words, we should have an area big enough to get 50 trees/ provenance (ex., Kenya Forestry Seed Centre adopts 50 trees per provenance, with a minimum distance of 100 m between trees). The location and geographical descriptions of the different provenances are given (Table 1).

Table 1. Provenance's collection region, geographic location, altitude and rainfall.

Locality	Region	Zone	Latitude	Longitude	Altitude
Shaba	SNNPR	South Omo	07-65-11-N	36-26-61-E	1977
Halaba	SNNPR	Halaba	07-19-13-N	37-95-67-E	2021
Loka Abaya	Sidama	Sidama	06-54-49-N	38-28-77-E	1918
Arsi Negele	Oromiya	West Arsi	07-07-38-N	38-55-59-E	1854.00
Megabi	Tigray	East Tigray	13-55-40-N	39-22-58-E	2038
Meraro	Amhara	North shewa	09-55-24-N	39-50-60-E	1599
Dangla	Amhara	West gojjam	10-51-46-N	36-35-37-E	1934.00
Negele Borana	Oromiya	Guji	07-07-87-N	38-55-71-E	1914
Metema	Amhara	Metema	12-54-47-N	37-21-21-E	2086.00
Chiro	Oromiya	West Harerge	07-44-00-N	36-13-00-E	2012
Debrebirhan	Amhara	North Shewa	39.51306	9.670278	2446
Arbaminch	SNNPR	Gamo	06-83-00-N	37-75-00-E	1850
Ziway	Oromiya	East Shewa	07-07-88-N	38-55-64-E	1941

The seed of *acacia seya*l was collected from different areas of the country (Ethiopia) as illustrated or mapped in Figure 1, where potential provenance has been used as a source of seed collection for plantation and forest seed sellers' purposes in the area. Most of the seed provenance was selected from the central and northwest Ethiopian localities of the country, where abundant seed is supplied for domestic purposes in recent years.

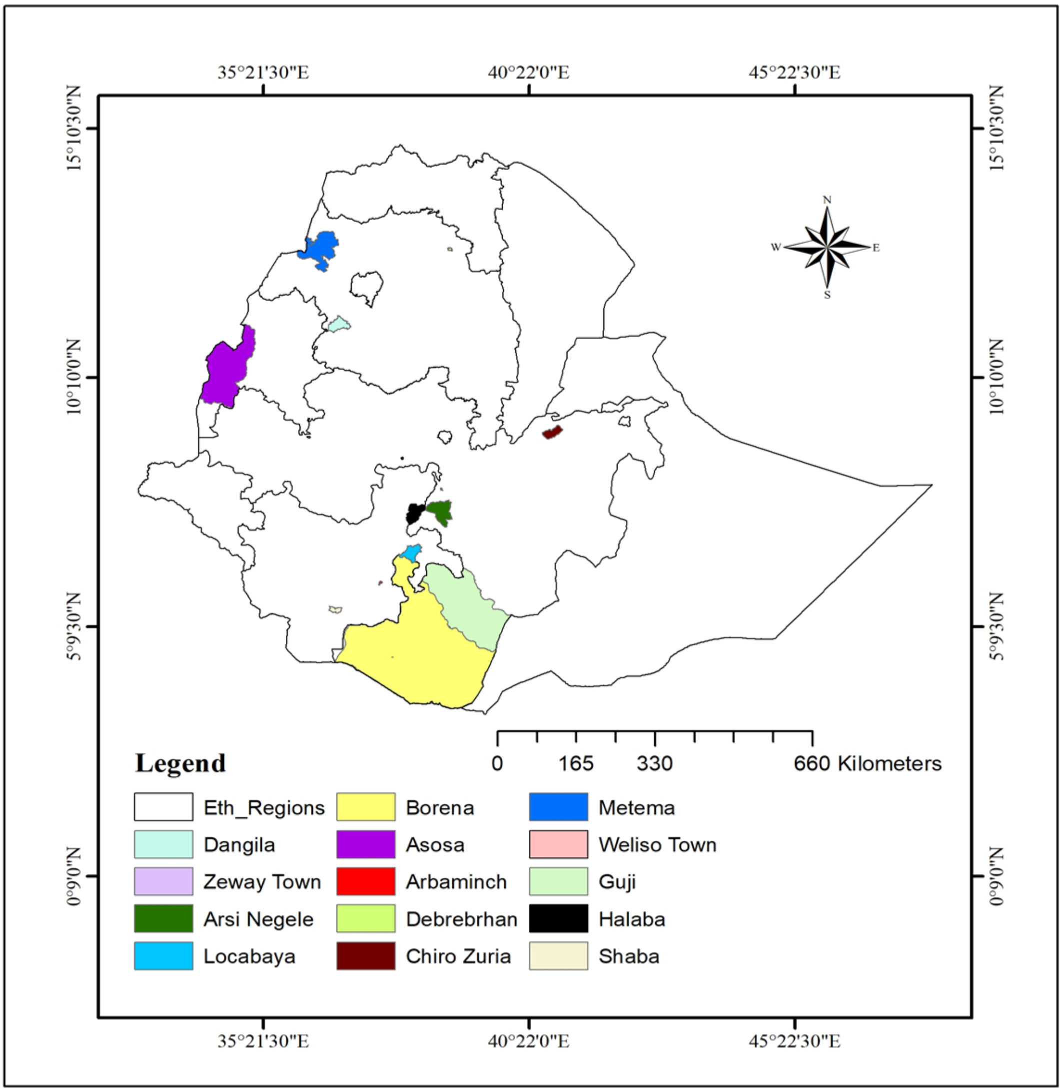

Figure 1. Map of seed provenance areas.

2.5. Data Collection

The shoot length/height of each species seedling was measured using a ruler in centimetres (cm), while root-collar diameter (RCD) was measured using a calliper among the provenances. In line with this, the number of leaf pairs of each seedling was counted. Seedlings' leaf, stem and root fresh and dry weights were measured employing sensitive balances. Seed germination was supervised daily until the average date of germination ended and seedling survival was supervised until the end of the experimentation.

2.6. Data Analysis

Collected data were analyzed and evaluated by using percentages. In addition, the statistical significance difference was determined by ANOVA and multiple comparison of Least Significant Difference (LSD) to show significance difference among the treatments using SAS Computer Software Programme.

3. RESULTS AND DISCUSSION

3.1. Seed Germination and Nursery Survival of Seedlings

Laboratory germination test, 1000 seed weight and survival count taken after the seeds had germinated were among the most important parameters of seed source influence in the study. The value clearly showed that localities near the experimental areas from which the seeds were collected was better in terms of almost all parameters (Table 2).

Table 2. Seed germination and nursery survival count.

Location	1000 seed Wt	lab G%	No of seeds sown	Germ 21 days	Germ 30 days	%Germ 45days	Survival 60dy	Survival 90Days	%Survival
Shaba	108.1	68	60	9	18	68	46	46	76.7
Halaba	161.6	82	60	8	23	79	47	47	78.3
Loka abaya	116.8	67	60	4	33	61	52	52	86.7
Arsi Negele	108.2	51	60	8	19	78	44	44	73.3
Megabi	105.9	70	60	3	35	59	48	48	80.0
Meraro	86	67	60	6	26	76	50	50	83.3
Dangla	119.8	60	60	10	34	73	51	51	85.0
Negele Borana	101	62	60	3	18	66	49	49	81.7
Metema	124	73	60	4	35	69	48	48	80.0
Chiro	116.4	69	60	4	30	62	47	47	78.3
Debrebirhan	114.4	72	60	8	22	65	48	48	80.0
Arbaminch	158.1	75	60	3	27	79	52	52	86.7
Ziway	132.6	78	60	5	34	82	51	51	85.0
CV	41	23	-	26	11	17	20	10	21

3.2. Growth Performance of Acacia Seyal Provenances

The growth performance parameters were evaluated for *Acacia seyal* provenances. Survival, diameter and tree height are important indicators of adaptability and performance evaluation in the evaluation of species and provenances [17]. Although the primary purpose of provenance evaluation was the early performance of provenances, it was evaluated in terms of root collar diameter, number of leaf pair, root length and seedling shoot height to select the best-performing provenance for the establishment of plantations in the Hawassa zuria District, Sidama region.

The seedling performance of *Acacia seyal* was significantly ($p<0.05$) varied among the provenances with respect to seedling height, root length, number of leaf pairs, and RCD. Results of the experiment revealed that there are statistically significant differences ($p<0.05$) among provenances of *Acacia seyal* in terms of seedling height. Accordingly, almost all *Acacia seyal* provenances evaluated in the study area had significant differences in seedling mean height compared to the provenance of Arbaminch (Table 3). The seedling height ranges from 22.4 cm to 10.3

cm, with the highest mean height recorded from Loka Abaya provenance (22.4 cm), followed by the Negele Borana provenance (21.3 cm) and Dangla (20.9 cm), while the provenance from Arbaminch (10.3 cm) had the least mean height in the tested area (Table 3). Height is usually considered an important variable in the evaluation of species and provenances, though this, of course, depends on the main uses of the trees. Apart from indicating productivity, height may also be seen as a measure of the adaptability of trees to the environment, tall provenances/trees usually being better adapted to the site than short provenances/trees.

Statistical analysis showed that there were significant ($p<0.05$) differences in mean root length between provenances. The highest root length was recorded from the Loka Abaya provenance (22.5 cm), followed by the provenance from Chiro (19.1cm), Dangla (18.3cm) and Meraro (18 cm), while the provenance from Arbaminch (10.2 cm) had the least seedling root length. The result indicated that the provenance from Loka abaya had good adaptation potential to the study site in seedling height and root length characteristics. This may be due to the similar agro-ecology of this seed source with the study area. Higher shoot length (seedling height) and RCD values are important for better survival rate and higher growth performance with better adaptation capacity of the seedlings in field conditions.

Table 3. Variation of seedling height, root length, number of leaf pairs and root collar diameter among provenances of Acacia seyal.

Trt	Seedling height	Root length	No of leaf pair	RCD
Shaba	18.5a	14.7bdc	14.5b	0.32bc
Halaba	19.6a	14.9bdc	13.2b	0.37bac
Loka abaya	22.4a	22.5a	16.5b	0.36bac
Arsi Negele	18.5a	16.7bc	12.8b	0.31b
Megabi	18.8a	14.1bdc	12.2b	0.32b
Meraro	20a	18bac	14.78b	0.33bac
Dangla	20.9a	18.3ba	13.4b	0.33bac
Negele Borana	21.3a	15.9bc	14.1b	0.45a
Metema	15ba	12.3dc	10.1b	0.26c
Chiro	16.9ba	19.1ba	18.78a	0.37ba
Debrebirhan	19.3a	17.6bac	14.3b	0.4ba
Arbaminch	10.3b	10.2d	9.1b	0.15d
Ziway	18.2a	17.2bac	11.78b	0.31bc
CV	41	32	44	34
LSD	0.92	0.33	2.35	0.021

Note: a,b,c,d,e; are words specifying statistical significance between treatments (e.g., they are separately written if treatments have statistically significant differences).

The leaf is the major site for photosynthesis or metabolically the most active parts of the plants as a result, various biogenic pathways take place and important part for survival and growth of plants. Provenance from Chiro showed a statistical difference over the provenances with highest number of leaf pairs, while the lowest number of leaf pairs found from provenance from the Arbaminch area (Table 3). Provenances also showed statistically significant differences in terms of root collar diameters. Analysis of variance revealed that provenance from Negele Borana (0.45 cm) shown higher root collar diameter, followed by provenance of Debrebirhan (0.4 cm), while the least root collar diameter was recorded with provenance of Arbaminch (0.15 cm). As discussed in Eler, et al. [18], root collar diameter of the seedling is good indicator for seedling field performance in terms of survival and growth. Plant populations exhibit genetic variation on several eco-geographical levels and such variation exist along ecological gradients in latitude, altitude and humidity [19]. So, many specialized populations have adapted to certain eco-climatic conditions [20]. The height and diameter growth of the species at the trial site indicate its suitability for small- and large-scale plantations.

3.3. Biomass of Seedling Provenances

Biomass is regarded as an important indicator of ecological and management processes in the vegetation. Statistically significant differences among provenances were detected for leaf, branch and root in both fresh and dry weight at (P< 0.05) (Table 4). Statistically, the highest biomass weight of leaf, branch and root fresh were recorded respectively on provenance of Megabi, Loka Abaya, and Halaba while the lowest fresh weight biomass was recorded from the Arbaminch provenance for all parameters. In turn, a large number of seedlings' leaves might contribute to a higher rate of photosynthesis, which in turn resulted in a higher growth rate [21]. In terms of fresh and dry weight biomass, statistically higher leaf, branch and root dry weight biomass were recorded from Megabi, Loka Abaya, and Halaba provenance. This shows the existence of positive relationships between above- and below-ground seedling growth parameters. The optimal growth of plants depends on the maintenance of an efficient balance between functions of roots and shoots that neither suffers serious deficiency in the supply of essential substances contributed by the other. Shoots are depending on the root for growth regulators in addition to water and mineral absorption that largely influences shoot growth.

Table 4. Variation of Leaf, Branch Root fresh and dry weight among provenances of Acacia seyal.

Trt	FWL	FWB	FWR	DWL	DWB	DWR
Shaba	2.71bc	2.37bdc	2.77a	2.9ba	1.47bdec	1.58b
Halaba	3.8ba	3.22ba	3.21a	3ba	2.23ba	2.16a
Loka abaya	4.33a	4.05a	2.51ba	2.94ba	2.62a	1.54b
Arsi Negele	3.58ba	3.04ba	2.49ba	2.35bc	1.71bdac	1.48b
Megabi	4.43a	3.32ba	2.98a	3.15a	2.07bac	1.95ba
Meraro	4.33a	3.37ba	2.63a	2.89ba	2.24ba	1.81ba
Dangla	4.23a	3.87a	2.77a	2.77ba	2.38ba	1.61b
Negele Borana	3.45ba	2.65bac	2.87a	1.91c	1.31fdec	1.43b
Metema	1.53dc	0.87e	1.27c	0.68d	0.34g	0.25c
Chiro	1.91dc	1.23ed	1.02c	1.02d	0.83fdeg	0.55c
Debrebirhan	1.93dc	1.02ed	1.54c	1.01d	0.55fg	0.56c
Arbaminch	1.19d	0.733e	0.98c	0.51d	0.5fg	0.26c
Ziway	1.64dc	1.32edc	1.63bc	0.75d	0.62feg	0.52c
CV	44	37	32	37	41	29
LSD	0.24	0.15	0.18	0.13	0.11	0.31

Note: FWL = Fresh weight of leaf, FWB = Fresh weight of branch, FWR = Fresh weight of root, DWL = Dry weight of leaf, DWB = Dry weight of branch and DWR = Dry weight of root. a,b,c,d,e; are words specifying statistical significance between treatment.(e.g. they are separately written If treatments have statistically significant difference).

3.4. Correlation Among Variables

Altitude and total rainfall were not correlated, but strongly correlation between altitude and average maximum temperature (89%). Mean monthly temperature and rainfall were correlated strongly (92%). Indicating that total vertical growth of plants was affected by available temperature; total seedling height and rainfall were directly and strongly correlated (89%). Seedling survival was negatively correlated with average maximum monthly temperature rather than average minimum monthly temperature.

Table 5. Correlation between seedling traits and environmental factors.

	Alt	TotR	Survl00	Ht	JulTmn	AugTmn	JunTmn	meanTmn	meanTmx
Alt	1.0000								
p-value	0.0000								
TotR	-0.0650	1.0000							
	0.7796	0.0000							
Survl00	0.0891	-0.3174	1.0000						
	0.7010	0.1609	0.0000						
Ht	0.0809	-0.8921	0.2201	1.0000					
	0.7275	0.0000	0.3378	0.0000					
JuITmn	-0.9241	0.2802	-0.2485	-0.2039	1.0000				
	0.0000	0.2186	0.2773	0.3754	0.0000				
AugTmn	-0.9268	0.1539	-0.2996	-0.0928	0.9816	1.0000			
	0.0000	0.5055	0.1870	0.6892	0.0000	0.0000			
JunTmn	-0.9363	0.2321	-0.3682	-0.1699	0.9823	0.9825	1.0000		
	0.0000	0.3114	0.1005	0.4615	0.0000	0.0000	0.0000		
meanTmn	0.9329	0.2361	-0.2919	-0.1668	0.9965	0.9924	0.9921	1.0000	
	0.0000	0.3028	0.1991	0.4698	0.0000	0.0000	0.0000	0.0000	
meanTmx	0.9177	0.1362	-0.4152	-0.0356	0.9054	0.9196	0.9600	0.9292	1.0000
	0.0000	0.5561	0.0613	0.8782	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Ht (Seedling height), Surv100 (Survival at 100%), meanTmn (Minimum temperature), meanTmx (Maximum temperature), JunTmin (June minimum temperature), JulTmn (July minimum temperature), AugTmn (August minimum temperature), meanTmax (Mean maximum temperature).
Seedling growth parameters like shoot and root were highly correlated/Highly affected by environmental factors (Minimum and maximum temperature) of the growing seasons, as seen in Table 5 below. The statistical values P-value and R indicate that environmental factors have a significant effect on seedling growth parameters.

4. CONCLUSION

Differences in growth between provenances show the successful adaptation of plants. The present study indicates that the performance of seedlings in the nursery site is highly affected by the source of seed. In order to get high, rapid, and uniform early performance of seedlings, selection of an appropriate seed source is important. Almost all provenances have a wide range of adaptability to the study area regarding all parameters. From the results of the present work and based on several observations furnished by researchers in the field of ecology, it can be concluded that *Acacia seyal* trees have fully naturalized in different eco-climatic habitats in various parts. Therefore, these provenances can be used as a seed source for the study area. Since the period of this study was short, at the nursery level, further progeny tests in the field should be undertaken for a longer period to obtain definitive recommendations for early selection.

4.1. Recommendation

Lokabaya, Negele Borena, Dangla, Halaba, and Arsi Negele provenances were seen to be better and more selective in terms of all growth parameters under nursery conditions. Finally, selecting and analysing additional provenances in future studies could be considered in order to get a more suitable provenance. Therefore, it is always advisable to identify the best seed sources adapted to different ecological regions and to breed them for efficient use.

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