Heliyon 10 (2024) e26514

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Effect of provenances on growth and stem form of 16-year *Juniperus procera* plantation in Injibara, Northwestern Ethiopia

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A R T I C L E I N F O

Keywords:
Form factor
Growth performance
Volume
J. procera Provenance
Plantation

A B S T R A C T

Juniperus procera Hochst. ex Endl. is an evergreen highland tree species reaching 30–40 m high and restricted to some mountainous areas. This tree is a species of great ecological and economic significance in supporting biodiversity, preventing soil erosion, and providing valuable resources. The study aimed at comparing the provenances effect on growth and yield performance of a 16-years-old *J. procera* plantation. This long-term experiment included eleven provenances from different regions of Ethiopia. It was laid out in a randomized complete block design with four replicates. The plot size was 100 m^2 with 2.5 m by 2.5 m spacing. Growth parameters such as height and diameter over a 1-m interval of standing trees were measured for sample trees. The results showed that the overall mean of basal area for 11 provenances was ranging from 4.4 ± 0.29 to 5.2 ± 0.33 m^2 ha^{-1}. The biggest (11.3 ± 0.14 m) and smallest (9.8 ± 0.16 m) mean height was obtained in the provenances of Kolobo and Dikisis, respectively. The mean volume of the stem ranges from 12.3 ± 0.93 to 17.9 ± 1.1 m^3 ha^{-1}. The highest and lowest form factor was obtained in the provenances of Gaynt (0.43 ± 0.02) and Hirna (0.32 ± 0.02), respectively. The generic form factor is 0.4 ± 0.01. Provenance Kolobo had the best growth rate in all growth stages with 1.4 m height greater than the poorest provenance Dikisis and 23% greater than the overall average volume (14.5 m^3 ha^{-1}) at age of 16 years. The variations in growth and yield performance among the provenances could be attributed to genetic differences and adaptation to the local environment. Provenances originating from similar altitude such as Kolobo's provenances showed better growth and yield performance, possibly due to their adaptation to the cooler and wetter conditions prevailing in the study area. Choosing provenances that are well-adapted to the local site conditions can lead to improved productivity and economic returns.

1. Introduction

Plantations have expanded in Ethiopia, increasing from 972 000 ha in 2010 to 1 203 000 ha in 2020 [1]. Of these, 2% are covered by Juniperus procera Hochst. ex Endl. species [2]. *J. procera* is a conifer species belonging to the Cupressaceae family. It is an evergreen highland tree reaching 30–40 m high and up to 1.5–2 m in diameter [3]. In Ethiopia, *J. procera* has durable, fungi and termite-resistant timber which had been used for the construction of Orthodox churches, as well as houses of early nobility [3,4]. Before the 1970s,' the species was overexploited for sawmill purposes. However, after 1970s,' the species was listed as main plantation species by the state

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https://doi.org/10.1016/j.heliyon.2024.e26514
Received 31 December 2022; Received in revised form 23 January 2024; Accepted 14 February 2024
Available online 15 February 2024

forestry department [3].

J. procera plantation also enhances better regeneration of native species. For example, the result of study at Menagesha-Suba dry Afromontane forest, showed higher number of regenerated understorey woody plants (18270 plants ha^{-1}) in 42 years old *J. procera*. This indicated that this tree species is important for ecological restoration [5]. Similarly, a study conducted in Eastern Amhara region of Ethiopia, indicated that *J.procra* dominant vegetation had a total of 1245 individuals, 696 seedlings and 549 saplings individuals that verifies the ecological significance of the species [6]. Another study on the same region of eastern parts also supported that *J. procra* dominated forest enhanced species composition with diversity of 3.29 and evenness of 0.85 values [7].

Although some information such as growth performance [8], volume and taper functions of *J. procera* [9] has been documented, little is known about the effect of provenance on the growth and yield performance of this species. Similarly, information such as germination of *J. procera* seeds in response to stratification and smoke treatments and regeneration response for area enclosure, population dynamics and genetic variability of species have been studied in natural stands [10–12]. Geographic distance, natural barriers and anthropogenic factors caused the genetic variability of *J. procera* [12]. However, most plantations in Ethiopia are characterized by poor establishment and management, resulting in low productivity and negative ecological effects [13]. Therefore, choosing better provenances with good productivity is essential to forest management. Better provenance also relates to the overall wood production and the quality of harvested timber, which varies in dependence on on-site conditions and selected forest reproductive material [14,15].

Previous studies indicated that the provenances had a variation in survival, early growth and seed morphological characteristics of *J. procera* [16]. Similarly, Fredrick et al. [17] found that provenances affected seed morphological characteristics, germination and seedling growth of *Faidherbia albida*. Hence, the selection of the best provenance of desired species for a given site or region is necessary to achieve maximum productivity in plantation forestry [16]. The structural composition analysis for *J. procera* indicates that this species is less represented in the lower-diameter classes, in which higher regeneration and recruitment are needed for a viable population of the species [13]. Similarly, growth and stem form of this species on provenance level were not well studied. As a result, in northwestern Ethiopia of Amhara regional state Banja district near Injibara town, an experimental site was established with *J. procera* species to study the effect of eleven provenances on early growth performances. Therefore, this study aimed to examine the effect of provenances on growth, yield and tree form of a sixteen-year *J. procera* plantation in the northern part of Ethiopia, Injibara. Understanding the effects of provenances on growth, yield and tree form of *J. procera* is important to determine which specific origins or geographic sources exhibit better growth rates and yield. This information is crucial for plantation forestry, as it enables foresters and land managers to select the most suitable provenances for specific planting sites. Moreover, these results could be useful for future tree breeding programs and establishment of *J. procera* plantations in similar highland areas in Ethiopia.

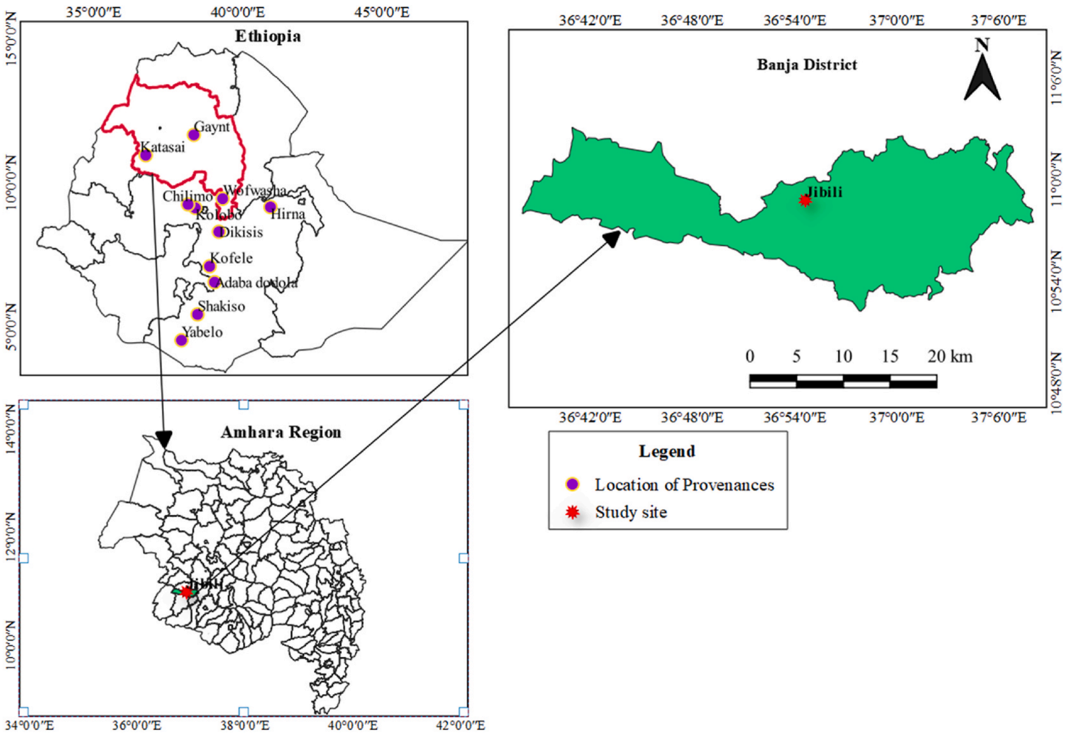

Fig. 1. Map of the study area and localities of provenances.

2. Materials and methods

2.1. Study area description

The study was carried out near Injibara town at the Jibili site which is geographically located at 10°59'15" to 10°59'19" N and 36°55'19" to 36°55'21" E of the Amhara region (Fig. 1). The site was selected due to environmental suitability for the species growth. The topography of the study site has an average slope of 17° with an elevation of 2455 m above sea level. The soils of the northwestern highlands of the country are largely from parent materials of volcanic origin and particularly the study area is brown in color, draining freely and medium to heavy texture. The district has unimodal pattern of weather condition with annual precipitation reaching 2241 mm and average temperatures of 18.7 °C [18]. The site was earlier planted with *Acacia decurrens* mixed with remnants of indigenous trees and shrubs.

2.2. Provenance collections

The geographic locations and climatic conditions of the seed sources are shown in Table 1. Yabelo and Shakiso represent the southern range of distribution of the species; Katasai and Gaynt represent the western distribution; Wofwasha, Chilimo and Kolobo represent the central distribution; and Adabadodola, Kofele, Dikisis, and Hirna represent the widest range of distribution of the species in the southeastern highlands (Fig. 1). Although the rotation age is affected by management, climate and agro ecologies, *J. procera* has a rotation age of about 40–60 years which is longer compared to exotic tree species [3].

2.3. Experimental setup

The study was carried out on permanent plots of *J. procera* provenance trial established in 2001 at the Jibili site by the Forest Research Center (FRC). The trial was arranged in a randomized complete block design (RCBD) with four replications and eleven provenances. The number of trees per plot was 25 with 2.5 m by 2.5 m spacing at a plot size of 0.01 ha.

2.4. Morphological measurements

To evaluate growth and yield of provenances, parameters of diameter at breast height (DBH) and height of nine inner trees from each plot were measured to avoid border effect. A meter tape was used to measure height, and a diameter tape was used to measure DBH. Height was measured annually from 2002 to 2018, while DBH was recorded beginning at age seven and continuing until age 16 when it becomes measurable. Both DBH and height measurements were taken to the nearest 0.1. For form factor development, 12 trees from each provenance were measured in their cross-sectional diameter in a 1 m interval along tree stem by using a ladder while standing to avoid destruction in 2018 at age of 16 years. These measurements were used to estimate the volume of a stem. The volume of each section was calculated using the Smalian formula [19]. The total volume was obtained by summing the volume of each section. The form factor was calculated as the actual volume divided by cylindrical volume. The basal area of the living tree was calculated as Basal area (g) $= \pi \times \frac{(\mathrm{DBH})^2}{4}$, where DBH is the diameter at breast height [20].

2.5. Data analysis

A univariate general linear model (GLM) was applied to analyze the collected and summarized data by considering provenance as a fixed factor and blocking as a random factor. Tukey's multiple range tests were used to separate significant differences between provenances (α, $\leq$0.05). ANOVA assumptions were considered by analysing the distribution of the residuals and homoscedasticity through Levene's test. The Statistical Package for Social Scientists (SPSS) version 25 was used for all statistical analyses.

Table 1
Geographical coordinates and climate of the seed collection sites.

Origin of provenances	Latitude (N) (°)	Longitude (E) (°)	Altitude (m)	Rainfall (mm)	Temperature (°C)
Yabelo	4.53	38.02	2040	744	18.9
Shakiso	5.43	38.58	1771	973	18.6
Adabadodola	6.55	39.17	2675	915	13.9
Kofele	7.10	38.41	2595	1228	12.5
Dikisis	8.30	39.32	2764	1265	12.9
Kolobo	9.13	38.50	2500	1610	15.7
Hirna	9.16	41.11	2575	1200	13.9
Chilimo	9.25	38.25	2550	1610	15.7
Wofwasha	9.45	39.45	2525	1047	14.4
Katasai	10.96	36.78	2410	2241	18.7
Gaynt	11.67	38.45	3069	1000	20.0

3. Result

Data on growth performance (16 years) of diameter at breast height (DBH), height and associated parameters like basal area and volume of 11 provenances are presented in Table 2. The overall mean of DBH at the age of 16 years was 15.4 cm. Across provenances, DBH ranged between 14.7 ± 0.44 cm (Katasai provenance) and 16.2 ± 0.42 cm (Kolobo provenance). Again, the Kolobo provenance had the greatest mean DBH throughout the 16 years, while the provenance from Katasai had the lowest DBH at all growth stages (Appendix 1). Differences in DBH among provenances were not significant (Table 3). The highest basal area was recorded in Kolobo provenance (5.3 ± 0.33 m^2 ha^{-1}) and the lowest in Katasai (4.3 ± 0.29 m^2 ha^{-1}). The overall mean tree height at the age of 16 years was 10.4 ± 0.06 m with provenance means ranging from 9.8 ± 0.16 (Dikisis) to 11.3 ± 0.14 m (Kolobo). There were significant differences in height among provenances ($p < 0.001$; Table 3) with trees from Kolobo performing best. The Dikisis provenance had a markedly lower height at the age of 16 than most of the other provenances. On the other hand, the Kolobo provenance still was the tallest (mean height, 11.3 ± 0.14 m) at the age of 16 (Table 2).

The overall average form factor for *J. procera* species is 0.4 (Table 2). There were significant differences among provenances in the stem form factor ($p = 0.001$; Table 3). Gaynt had the highest score (0.43), and the Hirna provenance had the lowest form factor (0.32). This study also showed that the provenance of Gaynt had less tapering than other provenances. Stem volume at age 16 years differed widely with provenances, ranging from 12.3 ± 0.93 (Hirna) to 17.9 ± 1.10 m^3 ha^{-1} (Kolobo) with the overall mean of 14.5 ± 0.30 m^3 ha^{-1} (Table 2). This indicates that provenance Kolobo is more productive than other provenances. Differences among the provenances were significant ($p < 0.001$; Table 3).

The annual growth rate of *J. procera* plantation provenances is presented in Fig. 2a and b and 3. The height increment was about 34% from age one up to age five. Then it increased with a gentle increment rate and provenance Kolobo was increasing in the best way than others (Fig. 2a). Throughout the 16 years, the Kolobo provenance remained the tallest while Dikisis had the smallest height along growth stages (Fig. 2a). The height of trees was grown rapidly, then increased gradually after the age of 5 years, reaching from 4.3 m at age of 7–10.4 m at the age of 16 years (Fig. 2a). The provenance from Dikisis had the worst performance at the age of 16, which is equivalent to the provenance of Yabelo's growth at the age of five, while provenance from Kolobo, Chilimo, and Gaynt had the best growth rate. The next best-ranked provenances in terms of height were Chilimo and Gaynt.

The increment rate of DBH (cm) was with an increasing rate from year 7 to year 8. Later on, the increment was with a decreasing rate in which provenance Kolobo has the highest and provenance Dikisis has the lowest increment rate at age of 16 years (Fig. 2b). Volume was increased about 40% from age 9 up to age 13 and the highest increment rate was observed for provenance Kolobo nearly twice that of provenance Dikisis (Fig. 3).

4. Discussion

The growth parameters such as height and diameter are usually considered as important variables in the evaluation of species growth characteristics [21]. Individual growth responses to tree parameters such as height, volume and tree form varied among provenances.) A considerable amount of variability was observed between the provenances for the growth traits as evidenced by CV (%). The provenance trial demonstrated that *J. procera* trees attained an average of 10.4 m height at 16 years with 0.63 m growth per year for the first 5 years but this growth rate declined to 0.54 m per year after age 6 (Fig. 2a). This shows that there exists an inverse relationship between growth rate and age. According to Johnson and Abrams [23] trees undergo physiological changes as they age. The larger size and the structural complexity are usually associated with lower photosynthetic rates, shifting of carbon resources to different parts of the plant, increase maintenance respiration costs, reduce the efficiency of water transport; these all tend to reduce growth [22,23]. The mean height of trees in Kolobo provenance was 11.3 m at 16 years of age, which is 1.4 m taller than the worst provenance of Dikisis. This means the Kolobo provenance produced 24% more volume than the average value of all provenances. The provenance effect was statistically significant for height, stem form and volume.

There were no significant differences among the 11 provenances in DBH at age 16, but trees from Hirna provenance were

Table 2
Provenance effect on DBH, height, volume and form factor of 16-year *J. procera* mean ± standard error (SE) (n = 36 = for DBH, height, volume and 12 for form factor). Similar supper script letters through each columns indicate no significant variation among treatments.

Provenances	DBH (cm)	Height (m)	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Form factor
Hirna	15.8 ± 0.49^a	10.4 ± 0.20 ^{ab}	5.1 ± 0 .35^a	12.3 ± 0.93^b	0.32 ± 0.019^a
Kolobo	16.2 ± 0.42^a	11.3 ± 0.14^a	5.3 ± 0.33^a	17.9 ± 1.1^a	0.42 ± 0.02^b
Adabadodola	15.3 ± 0.35^a	10.3 ± 0.16^b	4.6 ± 0.26^a	13.6 ± 0.76 ^{ab}	0.39 ± 0.016 ^{ab}
Katasai	14.7 ± 0.44^a	10.1 ± 0.18^b	4.3 ± 0.29^a	13.1 ± 1.0^b	0.42 ± 0.02^b
Dikisis	15.1 ± 0.33^a	9.8 ± 0.16^b	4.7 ± 0.20^a	13.1 ± 0.7 ^{ab}	.41 ± 0.021^b
Yabelo	15.4 ± 0.31^a	10.0 ± 0.18^b	4.8 ± 0.21^a	14.3 ± 0.72^{ab}	0.42 ± 0.015^b
Shakiso	15.2 ± 0.41^a	10.1 ± 0.17^b	4.5 ± 0.24^a	12.7 ± 0.77^b	0.38^{ab} ± 0.015
Wofwasha	15.2 ± 0.48^a	10.1 ± 0.21^b	4.8 ± 0.31^a	13.5 ± 1.1 ^{ab}	0.39^{ab} ± 0.018
Chilimo	15.7 ± 0.54^a	10.7 ± 0.17 ^{ab}	5.0 ± 0.38^a	16 ± 1.3 ^{ab}	0.41 ± 0.015^b
Gaynt	15.6 ± 0.40^a	10.6 ± 0.18 ^{ab}	4.9 ± 0.25^a	16.2 ± 0.98 ^{ab}	0.43 ± 0.01^b
Kofele	15.8 ± 0.46^a	10.6 ± 0.24 ^{ab}	4.8 ± 0.28^a	15.8 ± 1.1 ^{ab}	0.41 ± 0.017^b
Grand Mean	15.4 ± 0.13	10.4 ± 0.06	4.8 ± 0.08	14.5 ± 0 .3	0.40 ± 0.005
CV%	16.3	10.3	32.0	39.7	13.7

Table 3
Analysis of variance for DBH, height, basal area, volume (n = 36) and form factor (n = 12) of the 16 year 11 provenances of *J. procera* plantation.

Parameters	Source of variation	Degree of freedom	F	P
Height	Provenance	10	5.672	<0.001
	Block	3	3.008	0.03
	Error	361		
DBH	Provenance	10	0.957	0.611
	Block	3	1.331	0.491
	Error	361		
Basal area	Provenance	10	0.890	0.543
	Block	3	0.822	0.482
	Error	361		
Volume	Provenance	10	3.428	<0.001
	Block	3	1.448	0.228
	Error	294		
Form factor	Provenance	10	3.124	0.001
	Block	3	4.430	0.005
	Error	118		

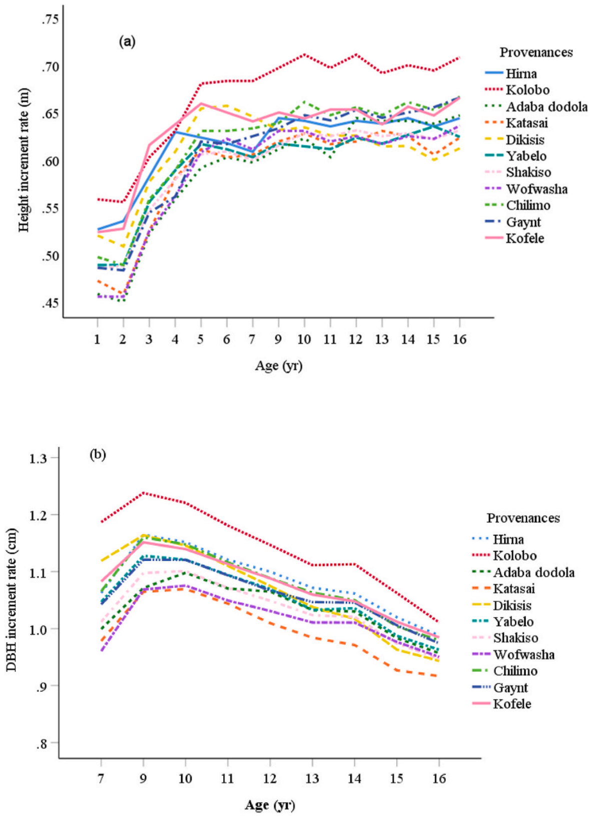

Fig. 2. Annual height (h) (a); diameter at breast height (b) increment rate of 16-year *J. procera* planation provenances at Jibili Injibara, Ethiopia.

noticeably poorer in stem form by age 16. This shows that the Kolobo provenance is more competitive in survival and growth than other sources. The good performance of Kolobo provenance compared to the other provenance may be partially explained by the right combination of genetics and site conditions [22]. Since slow growth is a problem in *J. procera*, selecting the best provenance in growth performance improves the growth characteristics [24]. Our observation from the provenance trails and rankings across ages shows that provenance Kolobo attained a maximum DBH and performed best in growth traits. The provenance Chilimo, Gaynt and Kofele showed similar rapid growth trends and performed better than the other provenances indicating their good adaptability. The range of provenance variation was large in all the growth traits indicating an ample scope for further selection.

Overall, the Kolobo provenance maintained its superiority in all growth traits becoming the most promising in comparison with other provenances. Provenance Dikisis performed poorest for growth traits. Previous studies show that variation in provenances affects the growth performances of various tree species [8,25]. This is because species widely distributed in a broad geographical range are

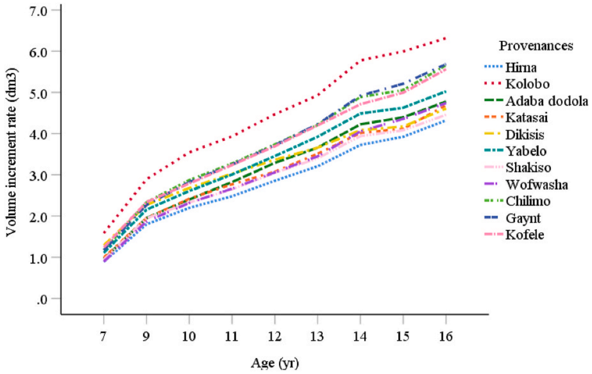

Fig. 3. Annual volume increment rate of 16-year *J. procera* planation provenances at Jibili Injibara, Ethiopia.

generally associated with provenance variation leading to variation in their adaptation ability in a particular area [26]. This is because a limited probability of inbreeding between provenances causes genetic variation [8]. The sources of seed from Kolobo provenance ensure appropriate sourcing of seed material and can have profound implications for the success of ecological restoration efforts within their geographical range [27]. According to these studies, consideration of ecologically important genetic variation within species is vital and this information should be integrated into seed collection strategies for ecological restoration.

The stem form factor of *J. procera* varies significantly with provenance mean ranging from 0.32 ± 0.02 for Hirna to 0.43 ± 0.01 for Gaynt. This shows provenance Gaynt is cylindrical by 25.6% than provenance of Hirna. Provenances of Gaynt, Kolobo, Katasai and Yabelo have higher form factor than other provenances. This indicates provenance (genotype) affects the stem form by determining growth of diameter and height [28]. Similarly, genetic gain is significantly higher for stem form of other tree species [29]. Knowing such form factor uses to accurate and consistent volume predictions, which is important for decision making and sustainable harvesting timber [30].

5. Conclusion

Provenances of 16-year *J. procera* plantation have shown an effect on growth and yield performance. From 11 provenances, provenance Kolobo showed the best performance in growth traits with the highest height growth at the age of 16 years. The result confirmed that choice of provenance greatly influences the overall success and productivity of the plantation. Hence, Kolobo provenance has better genetic traits for faster growth and development, leading to increased productivity in terms of biomass accumulation and wood volume. This is an important factor for commercial plantations, where timber is the primary product. In addition, it is an opportunity for genetic improvement of some provenances that may be better adapted to the specific environmental conditions. Form factor, which reflects the quality and suitability of the timber for specific uses, was also affected by provenance. Provenances showed better form factors, indicating that they produce timber with desirable characteristics such as straightness and uniform growth rings. Understanding the geographical distribution of ecologically relevant provenance for seed sources can have profound implications for the success of restoration efforts within their geographical range. The contrasting of provenances in growth traits demonstrate that afforestation with fast-growing species needs to consider the geographical distribution and adaptability of the species. Overall, the choice of provenance plays a crucial role in determining the success and productivity of *J. procera* plantations. Careful selection of provenances that are well adapted to the local environmental conditions is essential for ensuring optimal growth performance, increased yields, and improved form factors. Further research and experimentation can help to understand the ecological and economic significance of *J. procera*, the genetic diversity, conservation strategies and management practices to maximize the overall productivity and profitability of the species.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial or not for profit sectors.

CRediT authorship contribution statement

Sewale Wondimneh: Conceptualization, Wrting - original draft, Methodology, Formal analaysis, writing -review & editing. **Dessie Assefa:** Methodology, Formal analysis, Writing - review & editing. **Amsalu Abich:** Wrting - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank Ethiopian Forestry Development (the former Ethiopian Environment and Forest Research Institute) for the financial and logistic support during the whole research period. We would like to express our gratitude to Mr. Melkamu Abere, researcher at EFRI, and Mr. Asnake Gashu, technical assistant, who helped us during data collection.

Appendix 1. Mean DBH (cm) and height growth (m) of eleven provenances of J. procera among different ages after planting at Injibara, northwestern Ethiopia, mean ± standard error (S.E) (n = 36)

Appendix 1

Age (yr)	Parameter	Provenances										
		Hirna	Kolobo	Adabadodola	Katasai	Dikisis	Yabelo	Shakiso	Wofwasha	Chilimo	Gaynt	Kofele	Overall mean
7	DBH	7.5 ± 0.14	8.3 ± 0.17	7.0 ± 0.21	6.8 ± 0.19	7.8 ± 0.13	7.3 ± 0.17	7.1 ± 0.19	6.7 ± 0.19	7.4 ± 0.17	7.3 ± 0.19	7.6 ± 0.20	7.3 ± 0.06
	Height	4.3 ± 0.07	4.7 ± 0.06	4.2 ± 0.15	4.2 ± 0.10	4.5 ± 0.06	4.2 ± 0.09	4.2 ± 0.07	4.3 ± 0.11	4.4 ± 0.18	4.3 ± 0.09	4.4 ± 0.12	4.3 ± 0.03
9	DBH	10.5 ± 0.19	11.1 ± 0.19	9.9 ± 0.24	9.6 ± 0.19	10.5 ± 0.14	10.1 ± 0.22	10.0 ± 0.21	9.6 ± 0.25	10.4 ± 0.23	10.1 ± 0.21	10.4 ± 0.24	10.2 ± 0.02
	Height	5.7 ± 0.10	6.2 ± 0.07	5.6 ± 0.12	5.6 ± 0.11	5.7 ± 0.09	5.5 ± 0.12	5.7 ± 0.09	5.7 ± 0.14	5.8 ± 0.13	5.7 ± 011	5.8 ± 014	5.7 ± 0.03
10	DBH	11.5 ± 0.23	12.2 ± 0.23	10.9 ± 0.25	10.7 ± 0.22	11.4 ± 0.17	11.2 ± 0.2	11.0 ± 0.22	10.7 ± 0.27	11.5 ± 0.24	11.2 ± 0.23	11.4 ± 0.25	11.3 ± 0.07
	Height	6.4 ± 0.11	7.1 ± 0.99	6.2 ± 0.13	6.2 ± 0.14	6.2 ± 0.1	6.1 ± 0.14	6.1 ± 0.14	6.1 ± 0.14	6.5 ± 0.14	6.4 ± 0.12	6.4 ± 0.14	6.4 ± 0.04
11	DBH	12.3 ± 0.27	12.9 ± 0.24	11.8 ± 0.28	11.5 ± 0.25	12.2 ± 0.17	12.0 ± 0.21	11.8 ± 0.24	11.5 ± 0.31	12.3 ± 0 .27	12.0 ± 0.24	12.2 ± 0.25	12.1 ± 0.08
	Height	6.9 ± 0.12	7.6 ± 0.1	6.9 ± 0.12	6.8 ± 0.15	6.8 ± 0.11	6.7 ± 0.14	6.9 ± 0.15	6.9 ± 0.14	7.1 ± 0.13	7.1 ± 0.12	7.1 ± 0.15	7.0 ± 0.04
12	DBH	13.2 ± 0.30	13.8 ± 0.27	12.8 ± 0.27	12.1 ± 0.27	12.9 ± 0.21	12.8 ± 0.23	12.6 ± 0.27	12.4 ± 0.31	13.1 ± 0.31	12.8 ± 0.27	13.0 ± 0.30	12.8 ± 0.08
	Height	7.6 ± 0.13	8.4 ± 0.11	7.6 ± 0.14	7.4 ± 0.16	7.4 ± 0.11	7.5 ± 0.13	7.6 ± 0.12	7.5 ± 0.18	7.8 ± 0.14	7.8 ± 0.13	7.8 ± 0.16	7.7 ± 0.04
13	DBH	13.9 ± 0.34	14.4 ± 0.30	13.4 ± 0.30	12.8 ± 0.32	13.5 ± 0.24	13.5 ± 0.25	13.3 ± 0.30	13.1 ± 0.34	13.8 ± 0.37	13.6 ± 0.31	13.8 ± 0.33	13.6 ± 0.09
	Height	8.2 ± 0.14	9.0 ± 0.13	8.3 ± 0.14	8.1 ± 0.19	7.9 ± 0.14	8.2 ± 0.14	8.2 ± 0.13	8.1 ± 0.18	8.5 ± 0.14	8.5 ± 0.12	8.6 ± 0.19	8.3 ± 0.05
14	DBH	14.8 ± 0.42	15.6 ± 0.36	14.4 ± 0.33	13.6 ± 0.38	14.2 ± 0.28	14.5 ± 0.28	14.3 ± 0.34	14.1 ± 0.39	14.7 ± 0.43	14.6 ± 0.37	14.7 ± 0.38	14.5 ± 0.11
	Height	8.9 ± 0.13	9.8 ± 0.13	8.9 ± 0.15	8.8 ± 0.19	8.5 ± 0.14	8.8 ± 0.13	8.8 ± 0.14	8.8 ± 0.19	9.3 ± 0.13	9.1 ± 0.13	9.1 ± 0.19	9.0 ± 0.05
15	DBH	15.3 ± 0.45	15.9 ± 0.39	14.7 ± 0.34	13.9 ± 0.39	14.4 ± 0.31	14.8 ± 0.29	14.6 ± 0.38	14.6 ± 0.43	15.1 ± 0.47	15.1 ± 0.39	15.2 ± 0.29	14.9 ± 0.11
	Height	9.6 ± 0.14	10.3 ± 0.15	9.6 ± 0.15	9.2 ± 0.92	9.0 ± 0.17	9.3 ± 0.15	9.3 ± 0.15	9.4 ± 0.18	9.8 ± 0.14	9.7 ± 0.14	9.7 ± 0.14	9.6 ± 0.05
16	DBH	15.8 ± 0.49	16.2 ± 0.42	15.3 ± 0.35	14.7 ± 0.44	15.1 ± 0.33	15.4 ± 0.31	15.2 ± 0.41	10.2 ± 0.48	15.7 ± 0.54	15.6 ± 0.40	15.8 ± 0.46	15.4 ± 0.13
	Height	10.4 ± 0.20	11.3 ± 0.1	10.3 ± 0.16	10.1 ± 0.18	9.8 ± 0.16	10.0 ± 0.18	10.1 ± 0.17	10.1 ± 0.21	10.7 ± 0.17	10.6 ± 0.24	10.6 ± 0.24	10.4 ± 0.06

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