Growth performance of *Casuarina junghuhniana* provenances in two sites in Kenya

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Abstract

Two provenance trials of *Casuarina junghuhniana* were established in April 1999 in Uplands forest and Kiandongoro forest stations in Kenya on opposite sides of Aberdares Ranges as part of the ACIAR International Provenance Trial. The trials compared growth performance of 21 seed sources from the natural range of the species in Indonesia, and planted stands from Kenya and Tanzania. Fifteen provenances were common to the two sites while three additional different provenances were included at each site as the number of their seedlings was low. Assessments of the trials were carried out in April 2003 (for Uplands) and October 2005 (for Kiandongoro) for: height and diameter growth; axis persistence; stem straightness; density, thickness and angle of permanent branches; and length, thickness and stiffness of branchlets; results presented are for the growth parameters only. In 2015, health status of both trials was assessed including incidence and severity of pests and diseases. The growth characteristics differed significantly among the provenances and the land races. The average survival of the 18 provenances in Uplands was 53.4% while in Kiandongoro it was 78.3%. This is despite the fact that Kiandongoro trial was assessed at 6.5 years while the Uplands trial was assessed at 4 years. Provenance 18848 from Mt. Abang, Bali, Indonesia had the highest growth performance with 80%, 15 cm and 18.3 m (survival, diameter and height respectively). It was followed by 18844 from Mt. Tapak, Bali with 78.5 %, 13.0 cm and 12.8 m respectively. Other provenances worth considering for the Kenyan highlands include 18951 (Mt. Arjuno, East Java, Indonesia); 18846 (Mt. Pengalongan, Bali Indonesia) and 19239 (a land race from Muguga Kenya). The least adapted of the provenances was 18853 from Kwai Mission in Tanzania. However, the best performing provenances showed considerable within-provenance variation. There is therefore a need to establish stands of these suitable provenances and carry out selection of outstanding individual trees to optimize plantation productivity in future. The health status data revealed no major pests at either site but there was a significant difference in incidence of leaf blights between the two sites. The Kiandongoro site was severely affected by a leaf blight caused by a *Fusarium* species which

seemed to negatively affect growth there.

Keywords: *Casuarina junghuhniana,* provenance trials, highlands, growth, stem form, branching habit

1 Introduction

Casuarina junghuhniana is native to Indonesia where it grows naturally on the slopes of volcanoes and is a pioneer species of deforested land (Orwa et al., 2009). The species grows into tall forest trees of 15-25 m height and 30-50 cm diameter but can grow up to 35 m in height and 1 m in diameter. This species grows rapidly with a strong apical dominance. It was introduced in Kenya in 1956 and naturalized over time (Potgieter, 2014). Where it is endemic, annual average rainfall varies between 700 and 1500 mm and up to 2500 mm in Java (Pinyopusarerk et al., 2005). The mean minimum and maximum temperatures are 13°C and 28°C respectively.

There has been increasing enthusiasm to plant *Casuarina* in Kenya as an agroforestry tree species but unfortunately this has seen the mixing of *C. junghuhniana* and *C. equisetifolia* – the latter a lowland species. No trials of *C. junghuhniana* had been established in the country until the 1990s when CSIRO Australian Tree Seed Centre organised a coordinated seed collection from the natural occurrences in Indonesia and the planted land races in Australia, Kenya and Tanzania. There is therefore a need to assess the performance of *C. junghuhniana* in countries such as Kenya, Tanzania, Senegal, Uganda, China, India, Taiwan and Thailand where large-scale plantings have been established in areas with climates similar to its native range. Two provenance trials were established in Kenya among others established in other countries in Africa and Asia. This paper presents results from the two trials planted in Kenya (Uplands at the age of 4 years and Kiandongoro at 6.5 years). Though the trials are still standing to date, they have been greatly interfered with over time through illegal cutting for firewood and poles. However, photos of the standing trees have been obtained to guide in selection of provenance to promote for future plantings.

2 Materials and methods

Seedlots of 22 provenances of *Casuarina junghuhniana* and one of *Casuarina oligodon* in 5 g packages were received from the Australian Tree Seed Centre and sown in Muguga, Kenya. The *C. oligodon* did not germinate, while the other provenances had varying germination rates. After germination and development of the first leaves, the seedlings were pricked out into polythene tubes. When they had attained a height of approximately 30 cm, the seedlings were divided into two batches for two sites. These sites were: Uplands Forest Station (1° 3S′; 36° 39′E and 2354masl) in Kiambu County; and Kiandongoro Forest Station (0° 27′S; 36° 50′E and 2,300 masl) in Nyeri County, both on Aberdares Ranges. Due to varying germination among the diverse provenances, not all were replicated in the two sites, while others were also not replicated in the four blocks in a given site. Deliberate attempts were made to have all the seedlots established even where the particular seedlot could not fill the plot of 25 seedlings. In such situations, the available seedlings were planted first in the inner 3 by 3 planting spots of the plot. The outer row was then planted with seedlings of other seedlots that had excess seedlings and clearly marked in the plot layout. The details of the seedlots are shown in Table 1.

The Uplands Forest Station trial had 18 seedlots which include four local seedlots and one seedlot from Tanzania, and Kiandongoro Forest Station trial had 17 seedlots including five local seedlots. A randomized complete block design was used at each site, with 25 trees plot^{-1} planted at 2 m by 2 m and replicated in four (4) block replicates. Only nine seedlots had enough seedlings to be replicated in all four blocks at both sites.

Tree heights (ht) and their diameters (dbh) were measured between 1 and 4 years in Uplands and between 1 and 6.5 years in Kiandongoro. Plot mean survival was also calculated. Some qualitative traits

Table 1. Details of seed sources in the provenance trials of *Casuarina junghuhniana* established at Uplands and Kiandongoro Forest Stations in April 1999.

Prov No.	Soruce	Latitude (° ′ N)	Longitude (° ′ E)	Altitude (masl)	Site							
					Kiandongoro				Uplands			
					I	II	III	IV	I	II	III	IV
18951	Mt Arjuno, East Java, Indonesia	07 45	112 35	1350	√	√	√	√	√	√	√	√
17878	Noelmina River, Timor, Indonesia	09 59	124 06	170	√	√	√	√	√	√	√	√
18846	Mt Pengalongan, Bali Indonesia	08 50	115 15	1500	√	√	√	√	√	√	√	√
19491	Buat Soe, Timor Indonesia	09 51	124 16	800	√	√	√	√	√	√	√	√
19237	Meru, Kenya	00 07	037 37	1750	√	√	√	√	√	√	√	√
18844	Mt Tapak, Bali Indonesia	08 45	115 15	1500	√	√	√	√	√	√	√	√
18954	Mt Bromo, East Java Indonesia	07 55	112 55	2500	√	√	√	√	√	√	√	√
18948	Mt Kawi, East Java Indonesia	07 55	112 5	2000	√	√	√	√	√	√	√	√
17877	25km SW Soe Timor, Indonesia	09 54	124 14	550	√	√	√	√	√	√	√	√
19239	KARI, Muguga Kenya	01 16	036 36	2060	√	√	√	-	√	√	-	-
19238	KEFRI Hqs, Muguga Kenya	01 13	036 39	2080	√	√	-	-	√	√	-	-
18847	East Batu Kawu, Bali Indonesia	08 40	115 05	1500	√	√	-	-	√	√	√	√
19240	Muka Mukuu, Kenya	01 05	36 39	1460	√	√	-	-	√	√	-	-
18952	Mt Willis, East Java Indonesia	07 50	111 47	1500	√	-	-	-	√	√	-	-
18848	At Abang, Bali Indonesia	08 55	115 25	1500	√	-	-	-	-	-	-	-
19241	Thika, Kenya	01 02	37 12	1440	√	-	-	-	-	-	-	-
17844	Old Uhak, NE Wetar Indonesia	07 36	126 30	5	-	-	-	-	-	-	-	-
19490	Camplong, Timor Indonesia	10 05	123 57	600	-	-	-	-	√	-	-	-
18853	Kwai Mission Tanga Tanzania	04 19	038 14	1600	-	-	-	-	√	-	-	-
19489	Kapan, Kupang Timor Indonesia	10 13	123 38	600	-	-	-	-	√	-	-	-
18845	Mt Pohen Bali Indonesia	08 40	115 05	2000	-	-	-	-	√	-	-	-

on tree stem and branch features were observed and scored. These included: stem axis persistence, stem straightness, permanent branches density, permanent branches thickness, permanent branches angle and permanent branches length (Pinyopusarerk et al., 2004). The two trials were assessed for health status including incidence and severity of pests and diseases in 2015 at the age of 16 years.

3 Results

3.1 Diameter growth

In Kiandongoro, diameter growth among the provenances differed significantly. The provenances with the highest diameter growth were 18948, 18848, 18844, 18951, 18952, 18846 and 19239 all attaining at least 14 cm mean dbh at 6.5 years (Fig. 1). The poorest performing provenances were 19241 and 19491 with mean dbh less than 10 cm. In Uplands at 4 years, the best performing provenances were 18846, 18847, 18844, 18951, 18954, 18952 and 19239 with at least 10 cm mean diameter. Poor growth was registered among 18853, 17878, 17877, 19237, 19489 and 19491 provenances with mean diameters less than 8 cm.

At 20 years, five of the provenances had suffered high mortality with very few trees remaining. As a result, they were not included in the analysis. Higher diameter growth was recorded in Uplands where trees were sparsely distributed among all provenaces than in Kiandongoro where there was minimal disturbances of the plots. In Uplands, seven of the provenaces had attained a mean diameter of 30 cm. These were 19239, 18954, 19238, 18948, 19240, 18846 and 18844 (Fig. 2). The least growth was recorded among provenaces 17878 and 19491 at approximately 25 cm mean diameter.

In Kiandongoro, where reduced growth was registered, mean dbh ranged from 15.9 cm to 27.4 cm. Among the provenances, only two (18846 and 18948) had attained a mean dbh of 26 cm (Fig. 2).

3.2 Height growth

In Kiandongoro, the mean height ranged from 8.2m to 18.4m at six and half years. The best provenances were 18848, 18948, 18844 and 18846 with mean heights of around 17m (Fig. 3). The least performers were 19489 and 19241 with mean heights less than 9m. In Uplands mean heights at 4 years ranged from 4.5 m to 8.5 m. The best performing provenances were 18846, 18844, 18847, 18847 and 18948 with mean heights above 8m (Fig. 3). The worst performance was recorded for provenances 19491, 17877, 17878 and 19489 with mean heights less than 5 m.

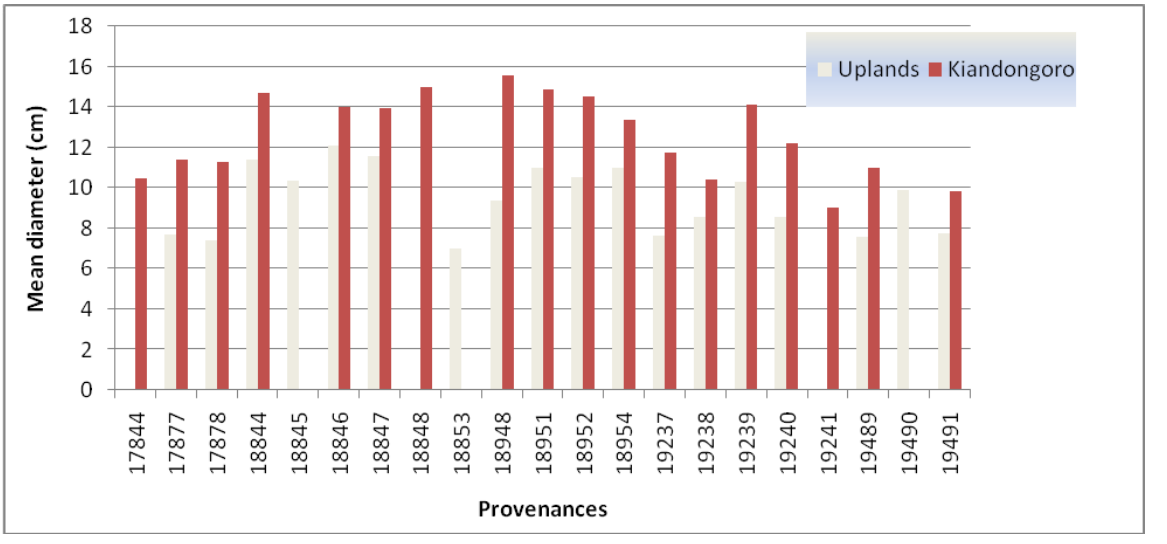

Fig. 1. Mean diameter growth of provenances at 4 years in Uplands and 6.5 years in Kiandongoro, Kenya.

In Kiandongoro at 20 years, the height ranged from 5.9 m to 22.2 m. The height growth pattern among the provenances generally remained stable relative to observations at 4 and 6.5 years with 3 out of 4 provenances still among the best performers (18846, 18948 and 18844). In Uplands, mean height ranged from 9.9 m to 20.7 m (Fig. 4). However, provenances that performed well in Kiandongoro also recorded above average height growth. For example, provenances 18948 (18.5m) and 18844 (17.1 m).

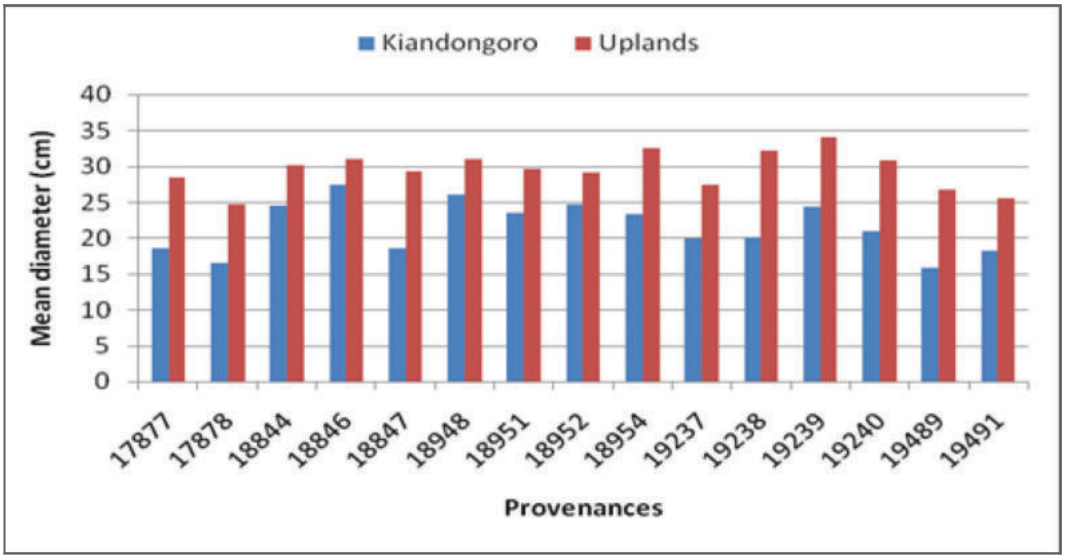

Fig. 2. Mean diameter growth of provenances at 20 years in Uplands and Kiandongoro, Kenya.

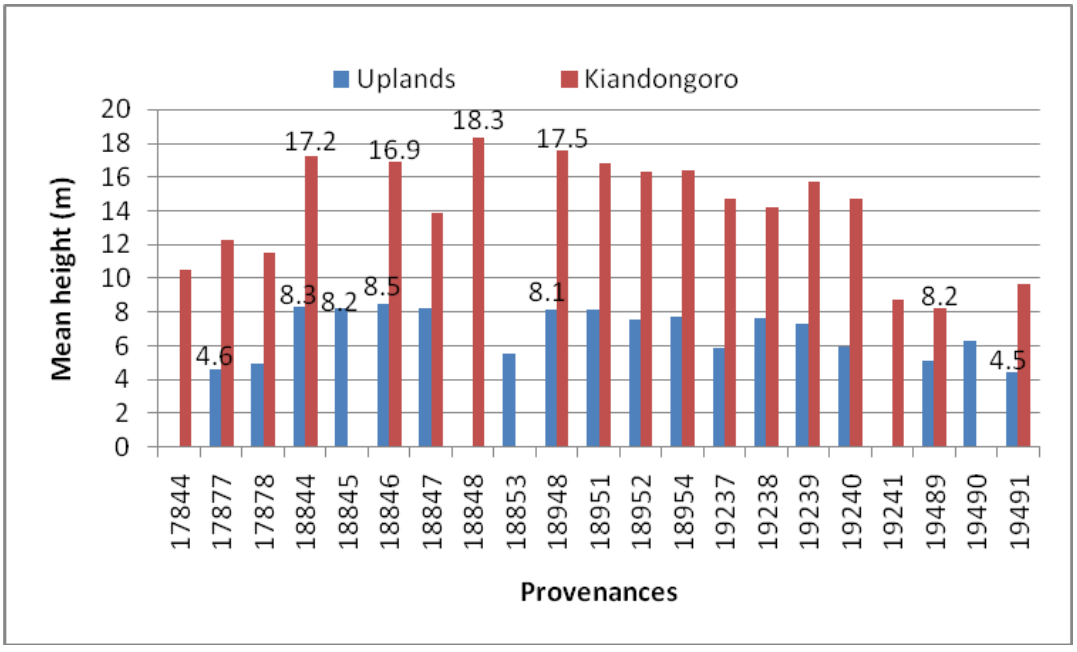

Fig. 3. Mean height growth of provenances at 4 years in Uplands and 6.5 years in Kiandongoro, Kenya.

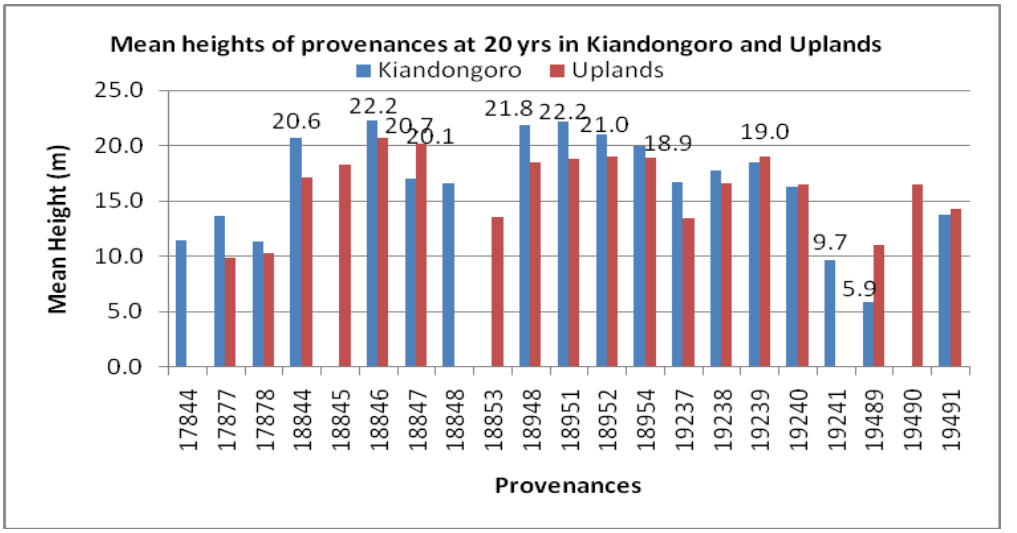

Fig. 4. Mean height growth of provenances at 20 years in Uplands and Kiandongoro, Kenya.

3.3 Survival of provenances

The survival rate of the provenaces was higher in Kiandongoro at 6.5 years than in Uplands which was assessed at four years (Fig. 5). In Kiandongoro, survival ranged from 60% to 93% among the provenances. A total of 14 out of the 18 provenances in the trial had survival rates over 70%. Uplands survival was lower, ranging between 26% and 86.7%, with only three provenances registering values higher than 70%.

3.4 Stem axis persistence, straightness and other qualititive parameters

In a score of 1-6, the following provenances were scored above a mean of 4: 18844, 18846, 18948, 18847, 18952 and 18954 in the two trial sites (Fig. 6). These provenances had no double leaders and generally no forking. In terms of stem straightness, there is very high variation among the provenances. The above

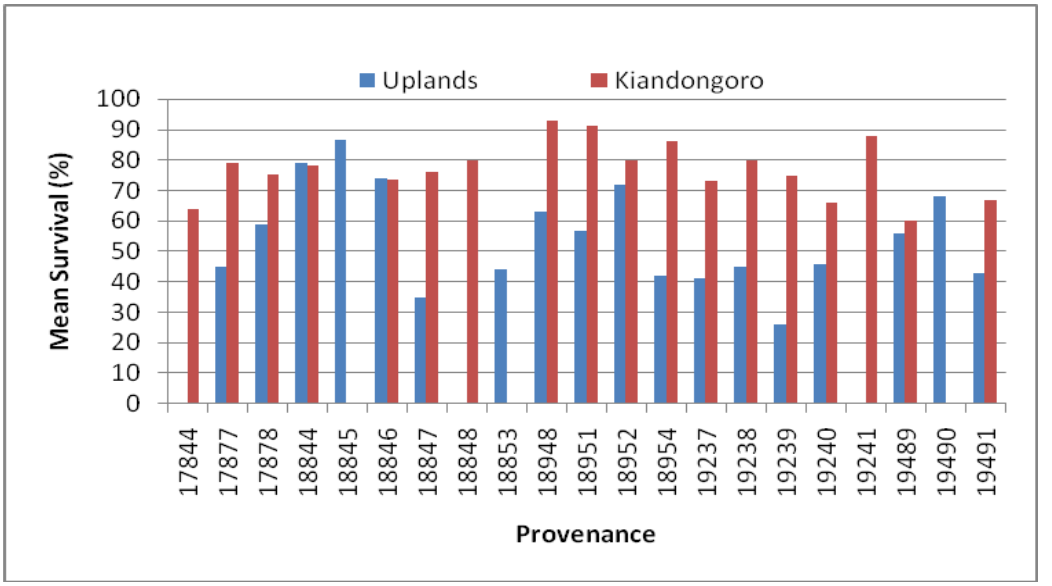

Fig. 5. Mean percent survival of provenances at 4 years in Uplands and 6.5 years in Kiandongoro, Kenya.

provenances recorded high values above 4 in 1-6 scale (Fig. 7).

In terms of branch density, provenances 18846 and 18954 had low values , a characteristic suitable for a tree targetted for interplanting with other crops. Among the provenances with high diameter and height growth, their branch length were above average with mean values between 1.8 and 2 (Fig. 8).

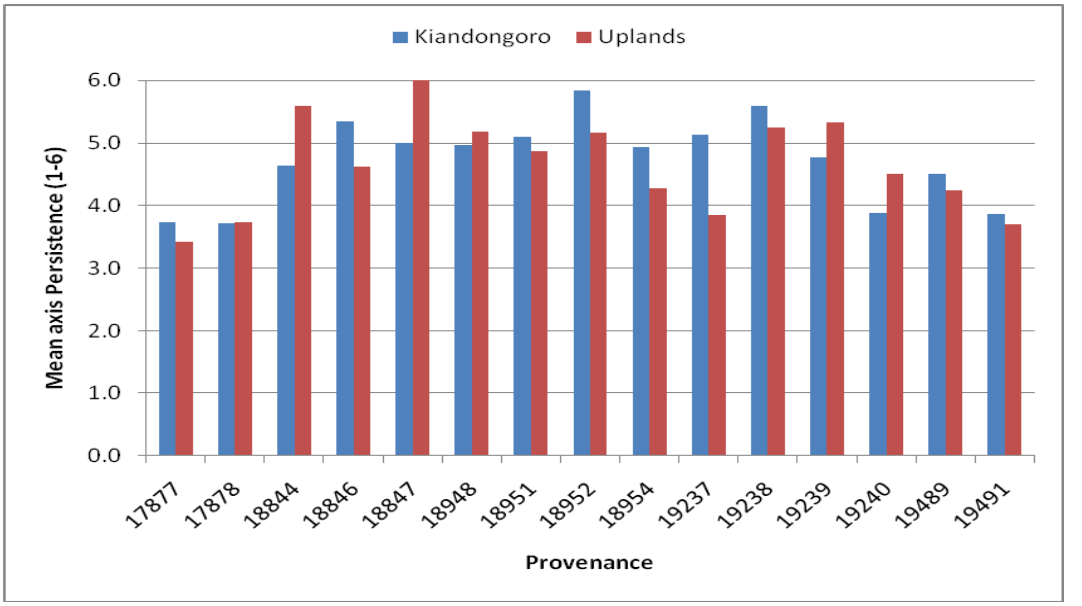

Fig. 6. Mean stem axis persistence among provenances at 20 years in Uplands and Kiandongoro, Kenya.

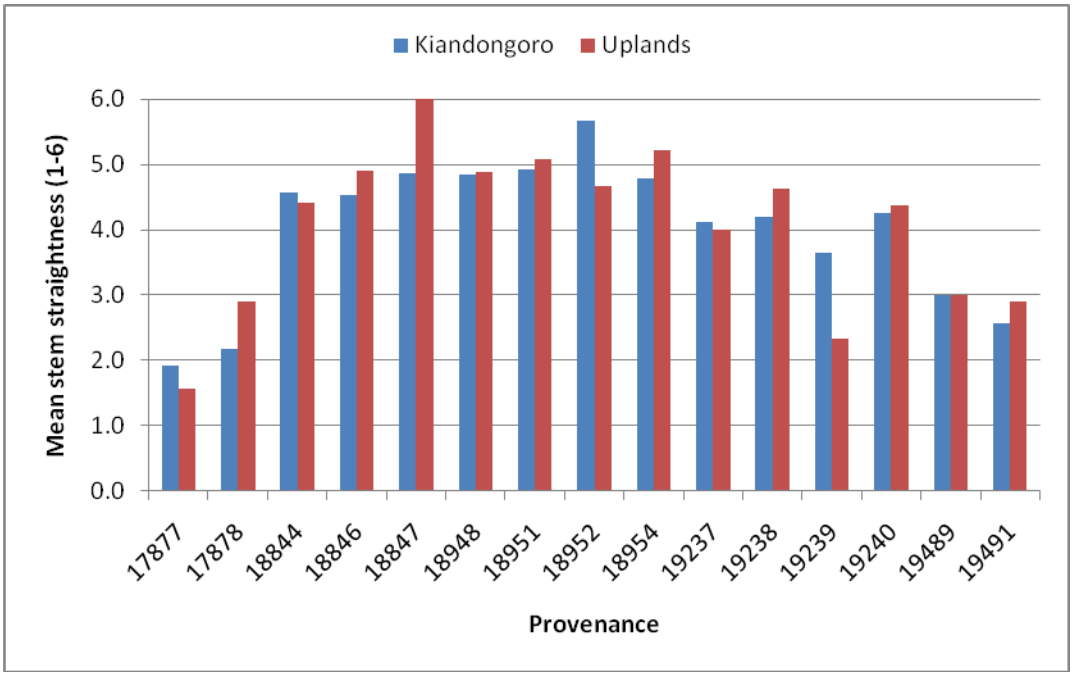

Fig. 7. Mean stem straightness of provenances at 20 years in Uplands and Kiandongoro, Kenya.

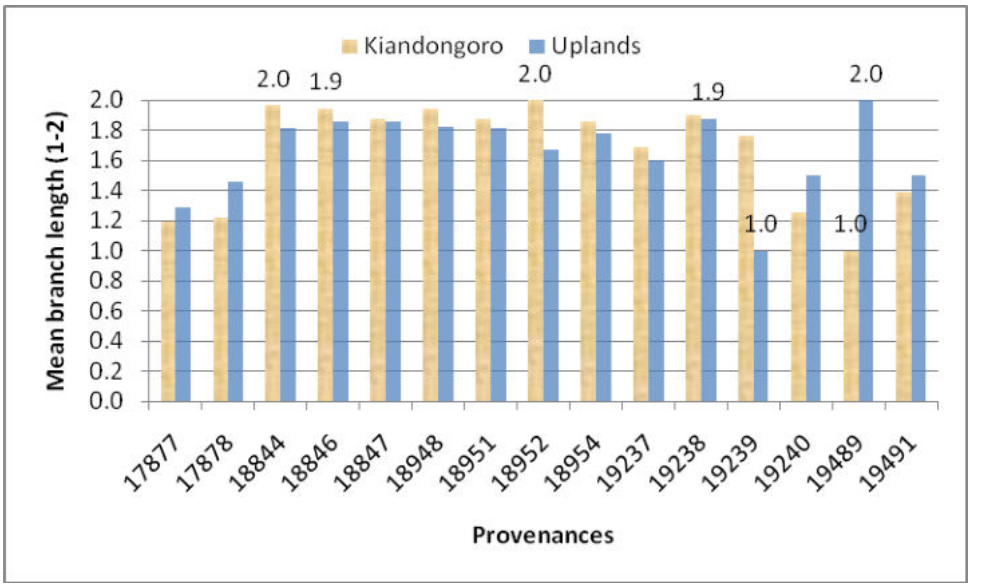

Fig. 8. Mean branch length of provenances at 20 years in Uplands and Kiandongoro, Kenya.

4 Discussion

The results indicated marked variation among populations of *C. junghuhniana* in many growth and morphological characteristics. From the results of the trial across the two sites, it has been observed that there is a close relationship between performance and altitude of source of any given provenance. There was a tendency for provenances from high altitudes to grow better than those from low altitudes. Provenances and land races from the lowlands were poorly adapted to the two trial sites that were above 2,300 m above sea level. These results are similar to those obtained from a provenance trial established in Tanzania with the similar seedlots. In Tanzania, high altitude provenances from Java, Bali and Lombok outperformed low altitude provenances from Wetar and Timor (Mwihomeke et al., 2002). The trial site in Tanzania was located at 1,500 m altitude. These results, also observed by Pinyopusarerk et al. (2005) in a wider set of trials, thus suggested a possible site-by-provenance interaction for *C. junghuhniana*. The land race from Tanzania may have performed poorly either because of inbreeding over successive generations associated with a possibly-narrow original range of introductions, because of its lowland origins, or both.

The trial revealed that there was considerable variation not only in growth performance but also in stem form and the branching habit. However, majority of the provenances with good growth had straight stems and light branches.

5 Conclusion

These trials demonstrated that there is great potential to use *Casuarina junghuhniana* as a commercial species in highlands of Kenya. However, considering the high variation among all provenances, selection of individual trees among the best performing provenances and land races is necessary to optimize plantation productivity for particular planting sites.

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