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Vol. 9(10), pp. 401-411, October 2015
DOI: 10.5897/AJPS2015.1334
Article Number: 87F240955772
ISSN 1996-0824

http://www.academicjournals.org/AJPS

African Journal of Plant Science

Full Length Research Paper

Morphological characteristic variation of eleven provenances of *Moringa oleifera* seedlings grown in the Northern Sudanese area of Burkina Faso

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Received 15 July, 2015; Accepted 23 September, 2015

This research investigated the morphological characteristic variation among West African provenances of *Moringa oleifera* in order to select the most suitable provenance for planting in Burkina Faso. A provenance experiment involving seven provenances from Burkina Faso, one from Mali, one Ivory Coast and one from Ghana was established in June 2014 in a randomized complete block design with three replications at Ouagadougou in the North Sudanese area of Burkina Faso. Plant growth traits (height, number of branches and pinnae, leaf length and width) and biomass production (above and underground biomass dry weight, under: aboveground ratio and total dry weight) were measured on two-week old and two-month old seedlings. The result indicates no significant correlation between morphological characteristics and agroclimatic data (longitude, altitude and annual rainfall) of the seed origin. Significant variations between provenances for morphological characteristics and biomass production ($P \leq 0.05$) were observed. Two-month old *M. oleifera* exhibited significant differences between provenances ($P \leq 0.05$). The average height ranged from 107-40 cm, number of branches from 15-8, number of pinnae per leaf from 12-5, leaf length from 44-16 cm and leaves width from 105-34 cm. The aboveground biomass productions ranged from 1-14 g, underground biomass production from 1-7 g, ratio of under: aboveground from 0.4-0.9 and total dry weight from 2-21 g. Five provenances from Burkina Faso (Gaoua and Dano in the South Sudanese area, Ouagadougou, Fada N'Gourma and CNSF in the North Sudanese area) and one from Ivory Coast (Niangon-Lokoua/Abidjan) in the sub equatorial area) showed superior performances. They can be recommended for planting in Ouagadougou and other areas with similar ecological conditions.

Key words: Leaves, pinnae, agroclimatic, correlation, aboveground and underground biomass.

INTRODUCTION

Moringa (*Moringa oleifera* Lam.) in the family *Moringaceae* is a plant indigenous to the sub-Himalayan regions in Northwestern India currently found in numerous countries situated in the tropical and

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sub-tropical regions across Africa, South East Asia and South America (Paliwal et al., 2011; Leone et al., 2015); where it is commonly used for animal forage, nutrition, medicine and water purification oil (Manh et al., 2005; Rashid et al., 2008). It is a fast growing, small to medium sized tree ranging between 5 and 12 m in height and tree canopy has an umbrella shaped crown with bi-(tri-)pinnate leaves, while the individual leaflets have a leaf area of one to two cm^2 (Muhl et al., 2011). Flowers are white to cream colored and zygomorphic. The tree bears 20 to 30 cm long fruit that once mature, change colour from green to brown revealing numerous round or triangular seeds with three papery wings (Arbonnier, 2002).

In West Africa, moringa leaves are mixed with other vegetables to make sauce. The use of the fresh and dried leaves as staple foods is very common in Burkina Faso. Leaves contain high amounts of total phenols and proteins and are a good source of vitamins and minerals: perhaps more than any other tropical vegetable (Ferreira et al., 2008). Moringa is used in many African feeding programs to fight malnutrition and its associated diseases, including blindness (Mulh et al., 2011). Fragrant flowers of moringa are also used as a source of vegetables and bee forage; twigs with leaves as fodder; green leaves as mulch and solid wood as energy source (Smith and Eyzaguirre, 2007).

Moringa is cultivated in tropical and sub-tropical areas with annual rainfall varying from less than 100 to over 1500 mm and different soils types (Nouman et al., 2012). It has been introduced into gardening systems because of its versatility (Palada and Chang, 2003; Nduwayezu et al., 2007).

Although moringa is grown throughout numerous agro systems, no large-scale commercial plantings have been reported, possibly as a result of the limited scientific data that is currently available on the morphological characteristics that control its survival and productivity. Therefore, further insights into the morphological characteristics of this species are needed before recommending its large scale introduction to home gardens of smallholders' growers (Scott and Sullivan, 2007). At present, data are not available to make reliable recommendations to garden landowners on the best seed sources and how the species might perform in various agroforestry systems. Therefore, the objective of this study was to evaluate the variations in morphological characteristics of the growth of *M. oleifera* at nursery stage for selection of seed sources suitable for plantation establishment under different geoclimatic environmental conditions.

MATERIALS AND METHODS

Study site

The study was conducted at the women gardening center "Amicale des Forestières du Burkina Faso (AMIFOB)" located at Ouagadougou, Burkina Faso (12°7'32''N, 01°40'24''W). The rainfall is uni-modal with a mean annual rainfall of the last 15 years data from the nearest meteorological station in Ouagadougou, of 950 mm $year^{-1}$, with the mean potential evapotranspiration of 177 mm. $month^{-1}$ and the mean temperature of 29.2°C $month^{-1}$ (Figure 1a and b). Soils are sandy clay to clay-sandy ferruginous leached with very low nutrient content according to French soil classification (Pallo et al., 2009). The common natural vegetation found at Ouagadougou is described as semi-deciduous open woodland. Main genera include, *Eucalyptus, Azadirachta, Mangifera, Vitellaria, Lannea, Piliostigma, Acacia., Ziziphus, Tamarindus* and *Combretum*.

Seed sources, experimental design and establishment

The experiment included eleven *Moringa oleifera* provenances of Ouahigouya (P1), Ségou (P2), Centre National de Semences Forestières (CNSF) (P3), Ouagadougou (P4), Koudougou (P5), Fada N'Gourma (P6), Bobo Dioulasso (P7), Dano (P8), Gaoua (P9), Tamalé (P10) and Niangon-Lokoua (P11) (Table 1). These provenances were selected from four countries, Burkina Faso, Mali, Ghana, and Ivory Coast and four climate areas according to their agro-ecological characteristics (Sahelian, Sub Equatorial, South and North Sudan). Seeds were collected in 2014 in plantation farmland from at least 12 mother trees per provenance. The experimental design was a randomized complete block design (RCBD) with three replications, and each plot represented a provenance planted at 5 x 6 rows in a contiguous arrangement of 20 x 20 cm (Figure 2). Plot measured 10 x 1 m and contained 30 trees and the distances between blocks were 2 m. Seed samples were pretreated with water for 24 h and sown in June 1^{st} 2014. Weeding was done twice during the rainy season. The seedlings were grown without fertilizers and pesticide.

Morphological measurements

The morphological measurements were performed on two-week and two-month old *M. oleifera*. Twenty seedlings from each provenance per block were selected randomly and their heights were assessed from root collar up to the terminal shoot using a measuring tape. At the age of two months, 20 randomly selected plants from each provenance in each block were labeled for counting the total number of branches per plant and pinnae per leaf.

Dry matter production

After two months from germination, all trees were harvested for dry matter measurements using an analytical balance. Each was separated into aboveground biomass (leaves, buds and stems) and underground biomass (roots), and dried at 70°C for 48 h using an oven.

Data analysis

All statistical analysis were carried out using ANOVA performed with JMP® Pro 11.1.1 (SAS Institute, Cary, NC, USA). Normality and homoscedasticity were graphically verified on residual plots of the linear models (Quinn and Keough, 2002). When effects were significant, the Duncan test was used for multiple mean comparisons to detect the significant differences between the

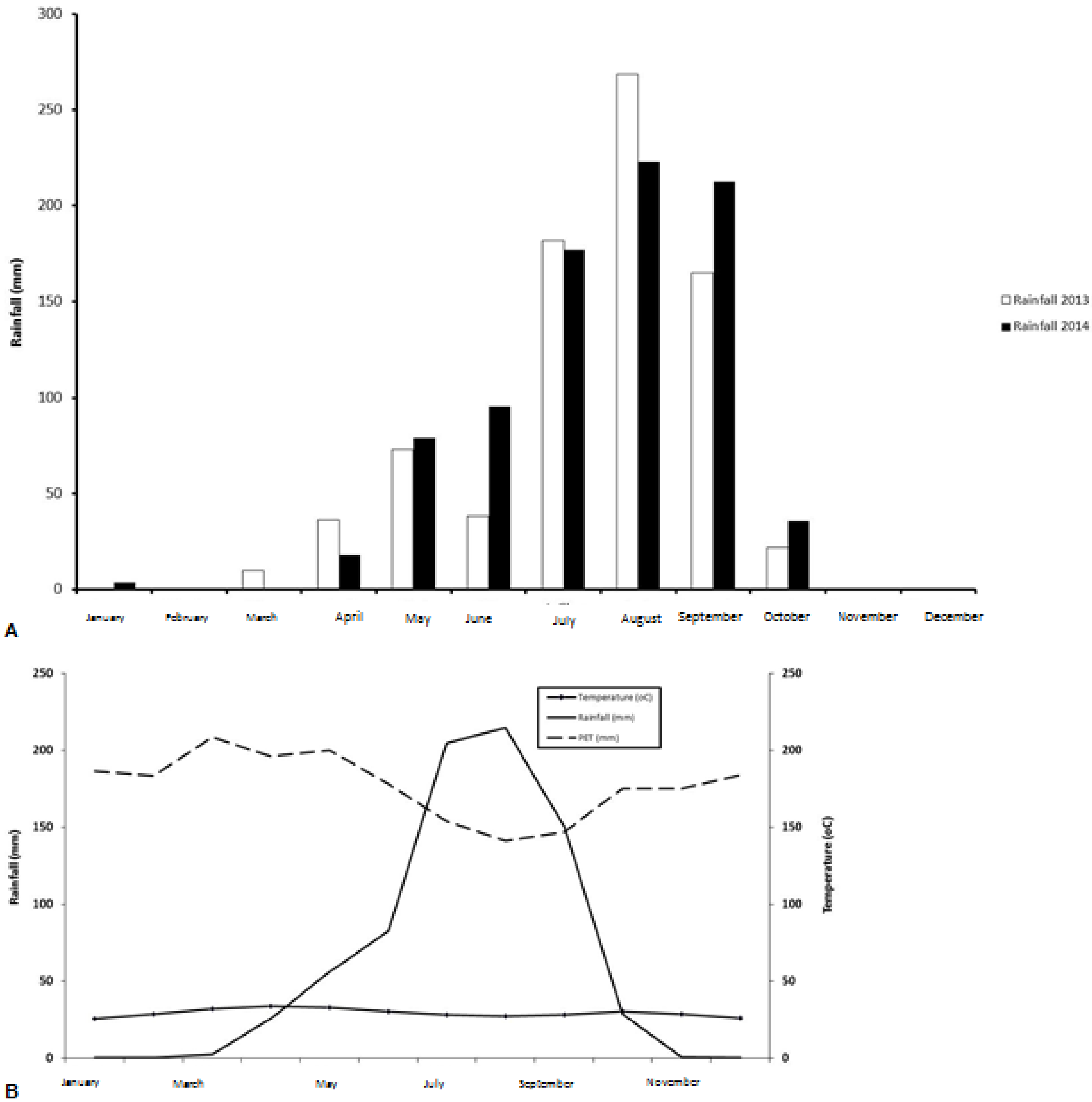

Figure 1. Mean rainfall of 2013 and 2014 (mm) (a); mean rainfall (mm), mean PET (mm) and mean temperature (°C) of the last 30 years (b) of Ouagadougou, the nearest meteorological station to AMIFOB site, Burkina Faso.

means. Statistical significance was fixed at 0.05. The correlation between the morphological characteristic variables and the geoclimatic data (altitude, longitude and average rainfall) of each provenance seed origin was assessed using scattered diagram to determine the linearity and the trend of the relationships.

RESULTS

Morphological traits

The height of two-week old seedlings showed significant differences ($P \leq 0.05$) among the studied provenances (Figure 3a). The provenance P9, P3, P1 and P11 exhibited the highest shoot length (average of 22 cm), which was significantly different from P2, P4, P5, P6, P7, P8 and P10. Significant differences ($P \leq 0.05$) were also observed in the height of two-month old trees (Figure 3a), with the provenance P9 exhibiting the highest shoot length of 117 ± 4.5 cm and the provenance P7 exhibiting the lowest shoot length of 40 ± 3.3 cm. The provenance P1, P3, P9 and P11 had the greatest average number of branches per two-week old seedling (6 branches), but

Table 1. Seeds origin of provenances of *M. oleifera* used in the study.

Provenance code*	Provenance	Country	Latitude (N)	Longitude (W)	Altitude (m)	Average rainfall (mm.year^{-1})
P1	Ouahigouya	Burkina Faso	13°30'04"	02°24'31"	306	500
P2	Ségou	Mali	13°22'05"	05°16'24"	294	500
P3	CNSF	Burkina Faso	12°30'07"	02°07'34"	304	800
P4	Ouagadougou	Burkina Faso	12°21'58"	01°31'05"	315	800
P5	Koudougou	Burkina Faso	12°15'04"	02°22'28"	308	800
P6	Fada N'Gourma	Burkina Faso	12°03'41"	00°21'30"	300	900
P7	Bobo Dioulasso	Burkina Faso	11°11′00″	04°17′00″	339	950
P8	Dano	Burkina Faso	11°09'00"	03°04'00"	287	950
P9	Gaoua	Burkina Faso	10°19'12"	03°10'12"	319	1000
P10	Tamalé	Ghana	09°24'27"	00°51'12"	169	1100
P11	Niangon-Lokoua/Abidjan	Ivory Coast	05°18'28"	04°06'19"	73	2000

*: This notation sequence was considered the correct one for all the manuscript.

a b

Figure 2. *Moringa oleifera* trial in the women gardening center of AMIFOB, a = two-week old seedlings plants; b = two-month old plants; Ouagadougou. Photo MCE DAO, Ouagadougou, 2014.

was not significantly different (P ≤ 0.05) from P2, P8 and P10 (Figure 3b). However, the difference was significant when compared with P4, P5, P6 and P7. The highest number of branches of two-month old trees was observed on the provenances P3, P4, P6, P8, P9 and P11 (15 branches). Provenances P10 and P7 had the smallest number of branches estimated at 8 and 9, respectively (Figure 3b).

Significant differences between provenances were found in leaf length and width (P ≤ 0.05) (Figure 4a and b). Two-month old *M. oleifera* from provenances P3, P4, P6, P8, P9 and P11 exhibited long and large leaves. The provenance P3 had the longest and widest leaves, measuring 45 and 105 cm, respectively. The provenances P3, P4, P6, P8, P9 and P11 had significantly (P ≤ 0.05) greater number of pairs of pinnae per leaf (Figure 4c). The provenances P3, P4, P6, P8 and P9 exhibited 12 pinna per leaf.

There was no correlation between the altitude, longitude and average rainfall of the seed source origin with the morphological traits (leaf length and width, number of pinnae per leaf and number of branches per tree) (Figures 5, 6 and 7).

Dry matter productions

The provenances displayed substantial variations (P ≤ 0.05) in dry matter production and location (Table 2). Aboveground biomass dry weight of the provenances varied between 1.2 and 14.0 g. The provenance P9 produced the highest aboveground biomass dry weight, which was significantly different from the other provenances. The provenances P1, P2, P7 and P10

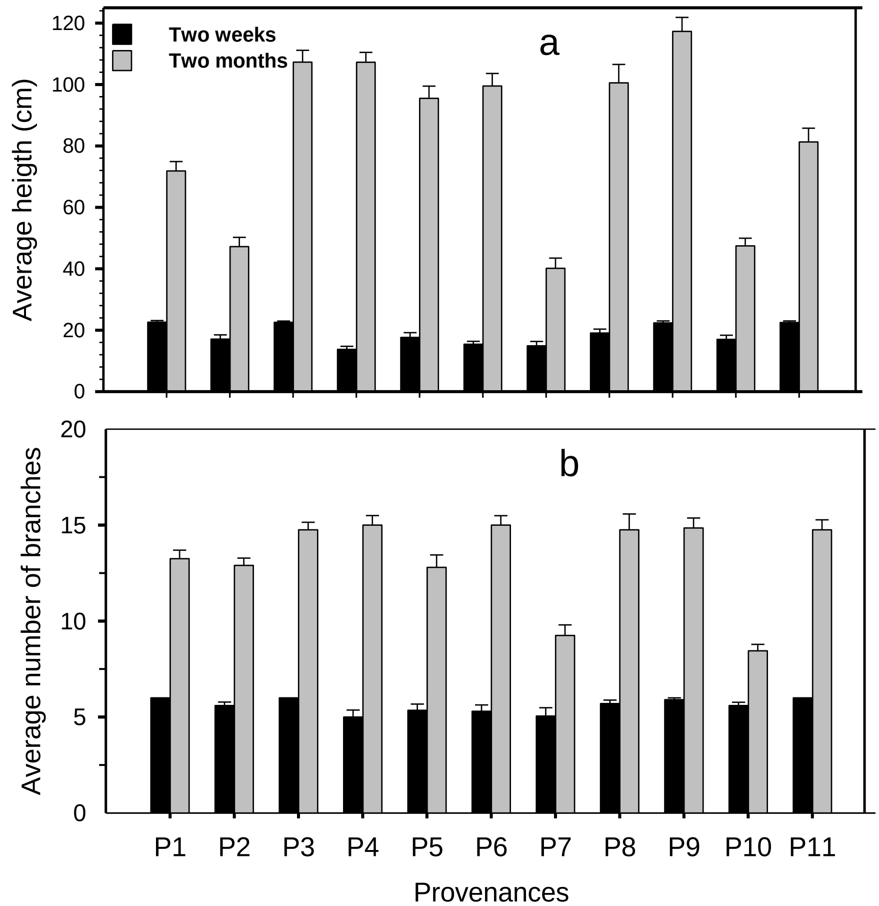

Figure 3. Morphological characteristics of *M. oleifera*: Average height of two weeks, and two months of age (a); average branch number of two weeks and two months of age (b). Values are means ± standard error.

produced the smallest aboveground biomass dry weight.

The underground biomass dry weight of the provenances varied from 1.0 to 7.4 g. The provenance P9 had the highest underground biomass dry weight, which was not significantly different from that produced by P3, P4, P5 and P6. However, significant difference appeared when they were compared with P1, P2 P7, P8 and P10, which produced the smallest underground biomass dry weight (Table 2). The underground biomass : aboveground ratio of the provenances varied from 0.4 to 0.9, and the highest ratio was shown by P10, but it was only significantly different from that of P1 and P8 (Table 2). Provenance P9 was also superior in total dry weight, which was significantly greater than the total dry weights produced by P1, P2, P5, P7, P8, P10 and P11 (Table 2).

DISCUSSION

This study evaluates the variations in morphological characteristics of the growth of 11 provenances of *M. oleifera* from different geoclimatic conditions of West Africa in order to select the seed sources suitable for plantation establishment under North Sudanese environmental conditions in Burkina Faso. Considering together all morphological characteristics and the biomass production, six provenances showed significant differences. The significant variability in the morphological characteristics was supported by previous studies on *M. oleifera* (Nduwayezu et al., 2007; Edward et al., 2014) and other species (Kozlowski and Pallardy, 1997; Ky-Dembele et al., 2014). The number of pairs of pinnae (5-12) is within the range reported by Arbonnier (2002). Moreover, the variation in number of branches may be related to genetic differences (Wright, 1976).

Despite the wide geoclimatic range of the sites sources, no correlation was found between provenances and the altitude, longitude and the annual rainfall for seedlings morphological characteristics. Thus, variations in seedling morphological traits among provenances

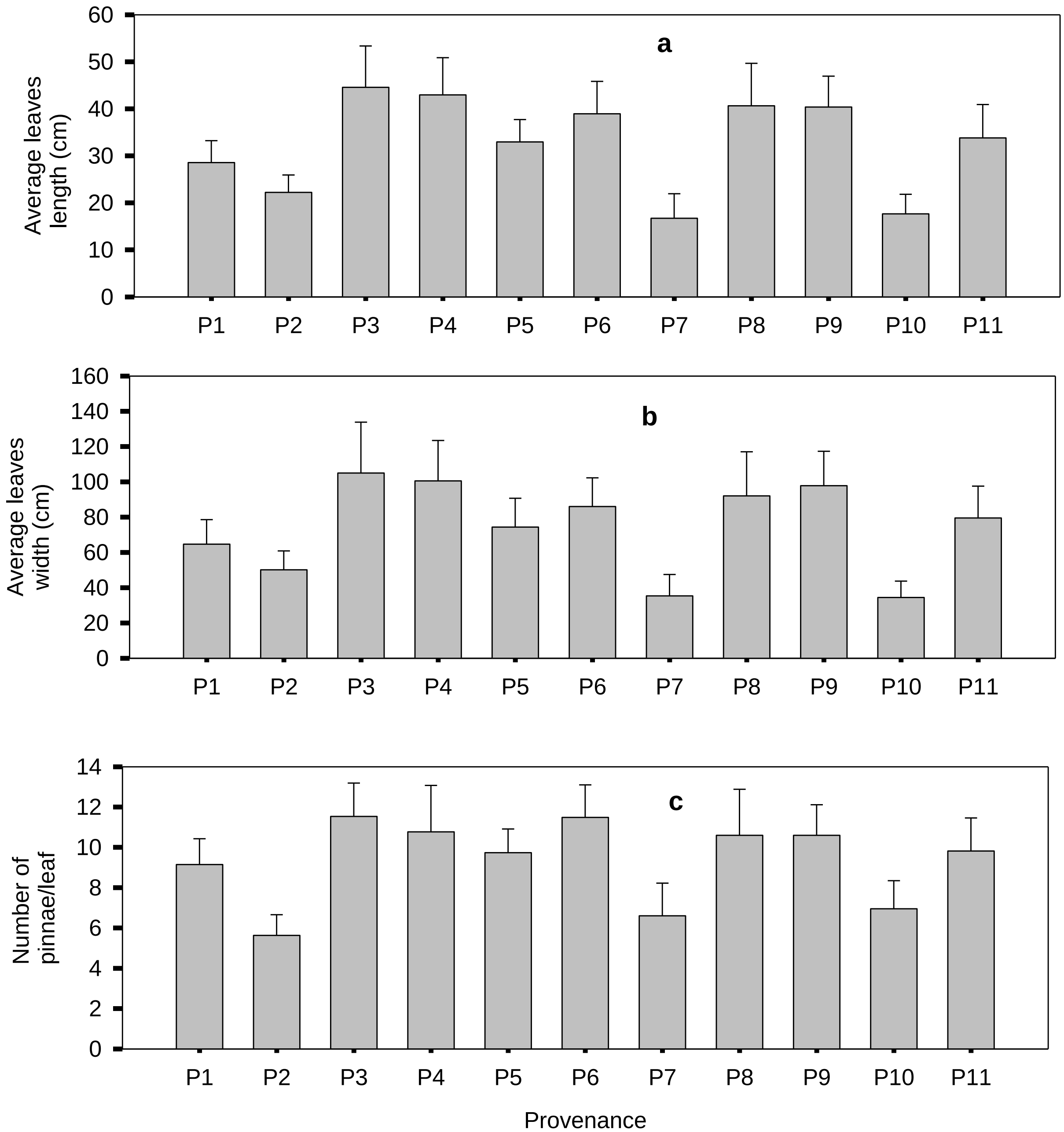

Figure 4. Morphological characteristics of *M. oleifera*, two months: leaf length average (a), leaf width average (b), number of pinnae/leaf (c). Values are means ± standard error.

cannot be explained by the average annual rainfall, altitude and longitude at the seed source origin. These results disagree with previous works reported by Abrams (1994), who showed the relationships between high rainfall areas and the plant morphological characteristics.

The significant differences in biomass production among the different parts of the provenances are consistent with the findings by Kundu and Tigerstedt (1998) in *Azadirachta indica* and Hardiyanto et al. (2004) in *A. mangium*. The good performance in above and underground biomass production of the provenances Gaoua (P9), Fada N'Gourma (P6), Ouagadougou (P4) and CNSF (P3) was attributed to its advantages in good growth in height, number of branches, pinnae and leaves at the study site.

The results of this study indicate the existence of

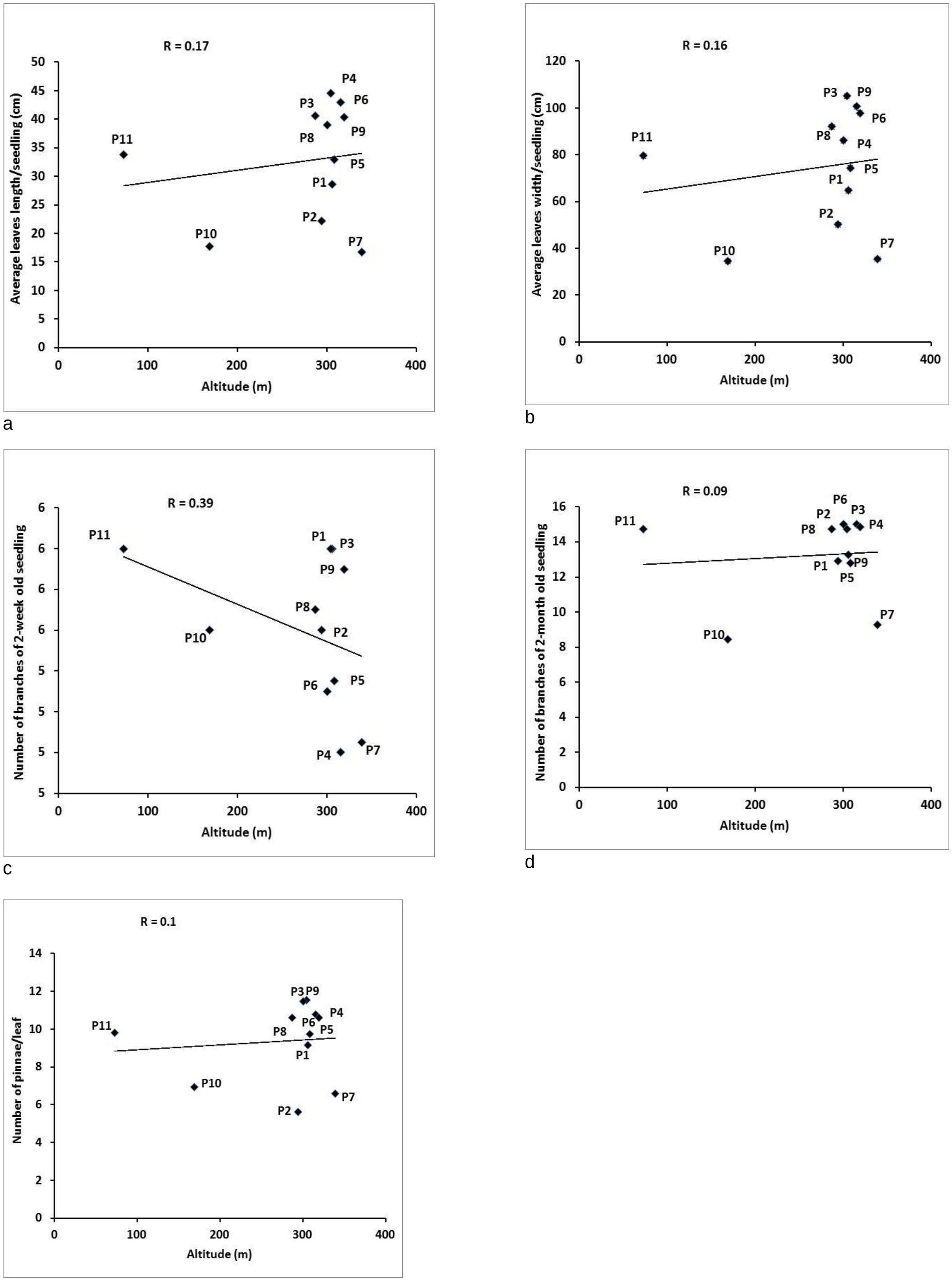

Figure 5. Correlation of altitude with leaf length average (a), leaf width average (b), average number of branches of two-weeks old plants (c), average number of branches of two-months old plants (d) and average number of pinnae per leaf (e) of eleven provenances of *M. oleifera*.

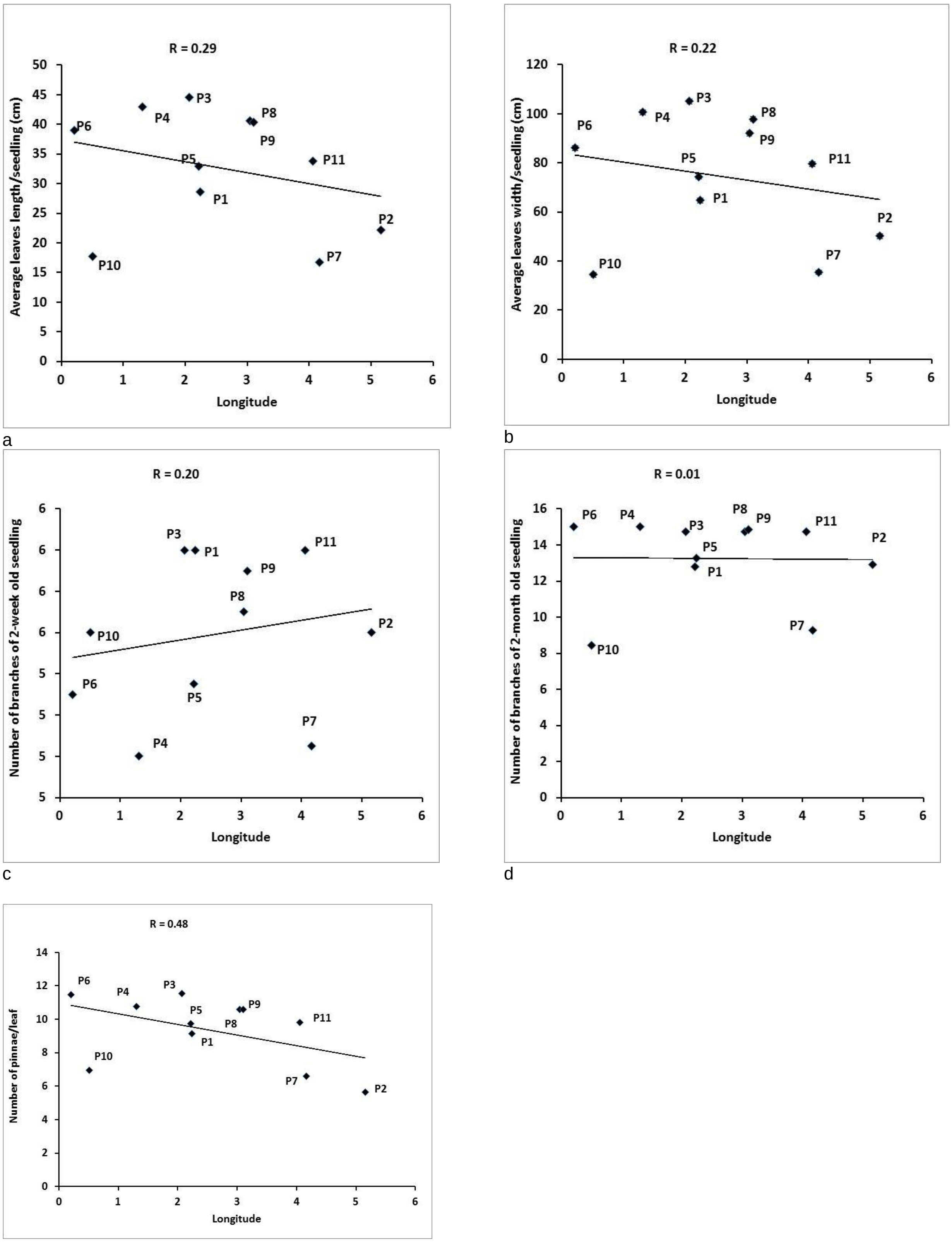

Figure 6. Correlation of longitude with leaf length average (a), leaf width average (b), average number of branches of two-weeks old plant (c), average number of branches of two-months old plant (d) and average number of pinnae per leaf (e) of eleven provenances of *M. oleifera*.

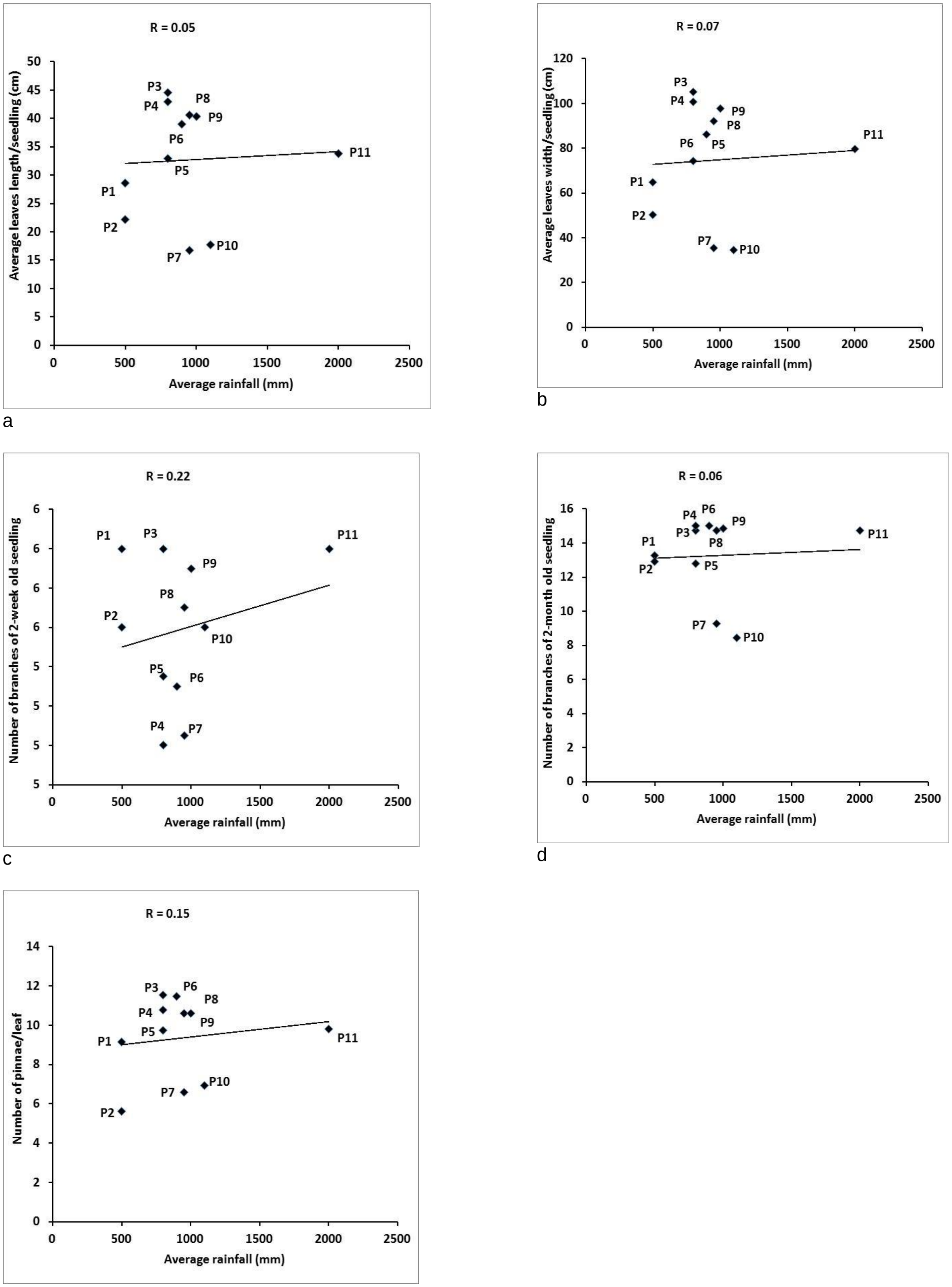

Figure 7. Correlation of average rainfall with leaf length average/seedling (a), leaf width average/seedling (b), average number of branches of two-weeks old seedling (c), average number of branches of two-months old seedling (d) and average number of pinnae per leaf (e) of eleven provenances of *M. oleifera.*

Table 2. Above and underground biomass of two-month old plants of *M. oleifera* from eleven provenances (the provenance codes indicated here is in accordance with the codes in Table 1 modified.

Provenance code	Aboveground dry weight (g)	Underground dry weight (g)	Underground biomass : aboveground ratio	Total dry weight (g)
P1	4.0 ± 0.5 de	2.2 ± 0.7 cde	0.5 ± 0.1b	6.2 ± 1.0 def
P9	3.4 ± 0.3 e	1.8 ± 0.2 cde	0.5 ± 0.1ab	5.2 ± 0.5 ef
P3	12.2 ± 1.1 ab	5.8 ± 0.9 abc	0.5 ± 0.1ab	18.0 ± 1.8 abc
P4	11.6 ± 1.6 ab	6.6 ± 1.4 ab	0.5 ± 0.1ab	18.2 ± 2.8 ab
P5	6.3 ± 0.8 cde	4.5 ± 1.0 ab	0.7 ± 0.1ab	10.7 ± 1.5 cde
P6	10.2 ± 1.1 abc	5.3 ± 0.8 ab	0.5 ± 0.1ab	15.5 ± 1.7 abc
P7	1.2 ± 0.2 f	1.0 ± 0.2 e	0.7 ± 0.1ab	2.2 ± 0.4 f
P8	7.9 ± 0.9 bcd	3.1 ± 0.3 bcde	0.4 ± 0.0b	11.0 ± 1.2 bcde
P9	14.0 ± 1.6 a	7.4 ± 1.3 a	0.6 ± 0.1ab	21.4 ± 2.4 a
P10	1.4 ± 0.1 f	1.2 ± 0.1 de	0.9 ± 0.1a	2.6 ± 0.3 f
P11	7.8 ± 1.0 bcde	5.2 ± 1.2 abcd	0.7 ± 0.1ab	12.9 ± 1.8 bcd

Values are means ± standard error. Means in the same column with the same letter (s) are not significantly different at P ≤ 0.05, according to Duncan multiple range test.

strong variations in seedling morphological characteristics and biomass production among the studied provenances. The climatic conditions prevailing in the seeds origins had no effect on the seedling's morphology and biomass production. The absence of significant correlations between the wide range of provenances from diverse geoclimatic conditions and the morphological traits and biomass production of *M. oleifera* was attributed to the ability of the species to grow on a wide variety of climate and soil types.

Conflict of interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The authors are very grateful to the support provided by the technician Zeba Abinatou from the Forestry Department of the Research Institute of Agriculture and Environment of Burkina Faso, Denis Walsh for the useful help in statistics and the members of women association (AMIFOB) for their tireless efforts in making this work a success.

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