Journal of Research in Biology

An International Scientific Research Journal

ISSN No: Print: 2231 –6280; Online: 2231- 6299

Original Research

Effect of altitudinal gradient on the dendrometric parameters of *Prunus africana* (Hook. F.) Kalkman at the East of Democratic Republic of Congo

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ABSTRACT:

Prunus africana is gregarious and abundant in the study area of Beni and North Kivu forests. The altitude has a significant effect on the dendrometric parameters like the thickness of the bark, the height and the diameter as well as the reconstitution of the bark after exploitation. The barked trees present reactions; especially those which have DBH higher than 80 cm showed good results. The bark regenerated with an average annual increase which varies according to the site of exploitation in mm per year. The productivity varies according to the altitude and areas of operation.

Keywords:
Altitudinal gradient, Dendrometric, *Prunus africana.*

Abbreviations:
NWFP: The North-West Frontier Province; NTFPs: Non-Timber Forest Products; DRC: Democratic Republic of the Congo; DBH: Diameter at Breast Height.

Article Citation:
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Journal of Research in Biology (2020) 10(1): 2780 -2786

Dates:
Received: 08 Nov 2019 **Accepted:** 13 Dec 2019 **Published:** 15 Jan 2020

Web Address:
http://jresearchbiology.com/documents/RA0708.pdf

Journal of Research in Biology

INTRODUCTION

Prunus africana (Hook. F.) Kalkman (Rosaceae) also called *Pygeum africanum* is endemic to Africa. It grows well in Afromontane forests between 900 and 3000 m altitude and in an optimum climate zone. This species has an economic, social and scientific impact for local people and for the international community (Samankeu, 2013). Historically, the operation of the timber is regarded as the only source of income from the forest. The foresters give no importance to NWFP. For them, logging concerns only timber. They consider NTFPs as a second product with no interest, whereas these natural resources play an important role in improving living conditions in the rural areas (Loubelo, 2012).

Evaluation of altitudinal stream on it's dendrometric parameters such as thickness, its DBH and height and the impact of *Prunus africana* bark harvest in terms of diametric structure and mortality helps to build good forestry management practices (Navarro *et al.,* 2008). In the sites of operation, no research on the altitudinal variation on the dendrological parameters have been conducted in better planning parameters as the mode of distribution of the species, thickness, stem diameter and the different responses of harvested stems. The central hypothesis of this research is that, wheather the altitudinal gradient would affect the thickness of the bark, tree height and diameter and trees on *Prunus africana* in the east of the Democratic Republic of Congo.

MATERIALS AND METHODS

Study area

Selected research sites were located in the territory of Beni, community-sector of Ruwenzori Lubero in the area of Walikale in Bapere and Wanianga sector in North Kivu Province of Congo. This region is characterized by a succession of rocky peaks in places separated by rivers and crevices. The altitude varies between 1200 (Mwenda Buligha and Lume Ibathama) and 2300 m for the research area. Peak Marguerite, of this area, rises to a height of 5,120 m .

These hills are separated by deep ravines often impassable whose combination with the hills offers a panoramic view of a heavily corrugated region and convoluted. This region is more rugged and has made it difficult and arduous opening transects, often impossible to establish the circular plots. The local climate of Ruwenzori massif has high humidity and spontaneous rain. Fog effects, which increase rainfall, are visible in Mwenda and elsewhere. The dry season is short, it only goes from December to February. The average temperature varies between 22°C and 25°C.

The month of July is the one that records the least precipitation, while the month of November recorded the highest rainfall of the year, (170 mm). The hottest month of the year is March, whereas July reports less hotter than other months.

METHODOLOGY

The data collection was carried out in plots installed on four sites viz., Lumë, Mwenda,

Table 1. Dendrometric parameters of *Prunus africana* with respect to its height

S. No	Zones	Mangurejipa	Walikale	Mwenda	Lume	P-value
1	Effective	55	55	55	55	-
2	Altitude (m)	1108	1975	1686	2045	-
3	Thickness (cm)	10.2 ± 2.2	16.7 ± 2.3	14.5 ± 1.9	17.2 ± 3.8	$1.61 * 10^{-6}$<0.02
4	Height (m)	11.8 ± 2.4	14.6 ± 2.3	13.8 ± 2.6	14.5 ± 1.9	$3.26 * 10^{-5}$<0.01
5	Diameter (m)	57.8 ± 15.6	72.6 ± 23.6	74.5 ± 24.5	63.3 ± 26.4	0.021<0.05

Table 2. Mortality and survival range of *Prunus africana*

S. No	Settings		Number of stems		Rate		Total
	Site	Average DBH	Live	Dead	Survival %	Mortality %	
1	Mangurejipa	56.9	32	13	71.11	28.89	45
2	Mwenda	66.5	38	7	84.44	15.56	45
3	Lume	69.4	41	4	91.11	8.89	45
4	Walikale	68.7	37	8	82.22	17.78	45

Mangurejipa and Walikale following the altitudinal gradient. These plots are from south to north in the dimensions of 250 x 1000 m, and are covering 25 hectares each. A total of four plots were established which represent an area of 100 ha for the four study sites.

In these plots, all trees *Prunus africana* diameter up to upper chest or equal to 10 cm were studied and geo referenced by GPS. To check the dry matter, operating standards and the different reactions, barks are harvested from the stems of *Prunus africana*. This study was done by collecting data on undeveloped stems since 2011, 2012, 2013 and 2014. Statistical calculations were done using MS Excel.

RESULTS

Changes in the dendrological parameters of *Prunus africana* with respect to altitude

Table 1 shows that the altitude has 1% significant effect on the thickness, and pitch. Finally, there is a significant effect at the 5% of altitude on DBH. Moreover, it appears from the analysis of the same table that the increase in thickness is proportional to the altitude. As for the height and average DBH, it increases proportionally with altitude and reaches the maximum in medium altitudes and slightly decreases in the high altitudes.

Mortality and survival after operation

The analysis in Table 2 shows that there were 45 barked trees at each site; the greatest mortality was seen at Mangurejipa 28.89% with a lower mortality at Lume.

Rate of reconstitution of the bark

Table 3 shows that the average annual increase of regenerated *Prunus africana* bark is almost the same in all operating areas. However, the first step taken after two years of operation. At that time, almost all peeled part was healed and covered. The tree bark is characterized by two faces differing by certain elements: colonization foams and the presence of rhytidome on non peeled portion, the difference in thickness and color.

Calculation of productivity of an usable stem of *Prunus africana* on farm sites

Table 4 is apparent that the average productivity of dry matter of a workable bark in North Kivu zones is 33.0 Kg, but with a high value in Walikale with 37.4 kg per bark and optimum to low at Mangurejipa averaging 30.3kg/bark.

DISCUSSION

Change in bark thickness in relation to the altitude

The results showed that the thickness increases significantly and proportionately with increasing altitude. In the atmosphere (troposphere), the temperature decreases with increasing altitude due to 0.54°C per 100 m. The proportional increase in the thickness of the bark with that altitude would be an ecological adaptation to cold for the species (Servant and Roux, 1990; Tadjuidje, 2011).

Similarly, in the collected samples of the undeveloped side of the control trees, the analyzes revealed the same result. The values found in the three operating sites (Walikale, Mwenda and Lume) were

Table 3. Regeneration rate of the bark of *Prunus africana*

S. No	Settings		Average bark thickness (m)		Operating time	
	Site (s)	Average DBH	Undeveloped	Exploited	Duration	AAM (mm)
1	Mangurejipa	56.9	10.1	4.6	3	1.53
2	Mwenda	66.5	16	7.6	5	1.52
3	Lume	69.4	19	7.9	5	1.58
4	Walikale	68.7	18	4.9	3	1.63

close to those found in Cameroon and Equatorial Guinea by Betti (2008), Betti and Ambara (2013) and Sunderland and Tako (1999).

Variation in height and DBH of the tree in relation to the altitude

The results showed that the altitude at a significant effect on the height is 1 ‰. It turned out that the height increases with altitudinal rise up to the maximum of medium altitude (1650 m on average) and that beyond this value above sea level, the height begins to decrease. Studies on the altitudinal variation in the height of the canopy shows that the height of it is inversely proportional to the altitudinal elevation.

The low values of the height of the stems of *Prunus africana* in the lower elevations were due to the fact that the sampled plot between 1279 and 1401 m above sea level to Mwenda is located in a highly anthropized medium and substantially all of the trees of *P. africana* which are studied and were in fallow land and fields. Indeed, the trees we observed in plantations and fields are characterized by branching at lower heights. Hence, limiting the growth of the apical bud gives smaller trees.

Juste and Perez (1995) found that in Equatorial Guinea on Bioko Island, the canopy height decreases from the low to the high altitude. They were distinguished as follows:

The low land forests (0-800 m)

They are srich and diverse with a canopy height of up to 40 m. The dominant species are *Ceiba pentandra* Gaertn, *Pycnanthus angolensis* (Welw.) Warb, *Erythrina senegalensis* DC, *Staudtia gabonensis* Warb, *Sterculia acuminata* P. *Beauv, Clorophora excelsa* Benth and Hooff and many species of the genus ficus.

The mountain forests (800-1400 m)

A forest where the canopy is low. It is usually composed of *Pycnanthus microcephala Warb, Coelocaryon preussii* Warb, *Sterculia oblonga* L. *and Chlorophora regia* A. Chev and a proportion of creepers, epiphytes and ferns as *Cyathea usambarensis* Domin and *C. manniana* Hook.

The mossy forest (1400-2500 m)

This is a low dense forest dominated by *Schefflera mannii* Harms*, S. hierniana* Harms*, Dracaena fragrans* and *Ficus thonningili* Blume.

The shrub group (>2500 m)

It is a dense vegetation whose height is up to 4 m. It consists mainly of *Hypericum lanceolatum* Lam*, Agauria salicifolia* Hook.f.ex Oliv *and Erica mannii (Hook.f.) Beentje.*

Similarly, Nkeng *et al*. (2010) found that the DBH and *Prunus africana* height increase inversely with the altitudinal elevation. They found that in Cameroon in four research sites namely DCC (242 m), Bova (896 m), Vikovi (2123 m) and Ichim (1888 m) average of 23.85 cm DBH were reported such as 17, 72 cm, 18.80 cm and 16 15 cm respectively. As for the height, they recorded an approximate average of 13.72±0.51 m in the DCC website (low altitude) and Vikovi 9.24±0.24 m (high altitude).

Table 4. Solids bark farm sites

S. No	Study area	Average altitude (m)	Average thickness (cm)	Average mass (g)	Average Volume (cm $^{3)}$	Average density	Average dried weight (kg)
1	Walikale	1975	1.8	467.7	530.5	1495.5	37.4
2	Lume	2045	1.9	773.2	1103.2	1309.4	32.7
3	Mwenda	1686	1.6	435.35	458.56	1260.2	31.5
4	Mangurejipa	1108	1.01	128.23	267.14	1211.4	30.3
5	Total	6814	6.31	1804.48	2359.4	5276.5	131.9
6	Average	1703.5	1.5775	451.12	589.85	1319.125	33.0

Reaction rods of *Prunus africana* that cope with the stress caused by harvesting the bark

The scale of 0 to 5 depending on the extent of tree defoliation issued by Sunderland and Tako (1999) was shown in Table 4. Out of 46 barked trees (different years), 39 or 84.8% were alive and seven or 15.2% died. In addition, among the seven dead stalks, six have diameters greater than 80 cm. It should be predicted that adult stem are less resistant to debarking because they have cells that are in the process of losing pluripotency. Furthermore, Navarro *et al.* (2008), for their study on Afromontane forest structure *Prunus africana* where showed that, the percentage of dead trees (DBH to >30 cm) was over 10% while the lightly exploited populations showed no severe mortality. This reflects the intensive crop that mainly affects the large trees.

Similarly, on Mount Cameroon with a population of 1789 debarked trees , a mortality rate of 22%, a 39% survival rate and 39% of individuals in decline was recored (Minifof, 2007). Kourogue (2010), found that, based on 15 years of study of the growth of the mortality of forest trees of Afromontane of South Africa, the mortality rate of trees whose DBH is greater than 10 cm averaged 0.71% per year. Mortality of *P. africana* whose DBH greater than 30 cm in wild populations with commercial harvesting could be more than 50 times the natural mortality. Compared to the results of all this work, the percentage of mortality of *Prunus africana* in the Eastern sampling areas of the DRC does not deviate from different mortality rates found in the above mentioned areas. This confirms our second hypothesis that trees harvested for their bark by rotation have various reactions to stress caused by harvesting the bark.

Reconstitution time of the bark after operation

The results in Table 3 shows the average annual increase of regenerated *Prunus africana* bark as 1.5 ± 0.6 mm. Considering this value, it is necessary to extrapolate over 10 years and predict that the thickness reaches 15 mm on average. In other words, it takes 10 years for the peeled portion to be operated for a second time. Parliment of Congo fixed a rotation of 12 years or atleast a half rotation of 6 years for the forests of Ruwenzori (ICCN, 2013; ICCN, 2015 a and b). It was said that this rotation contributes to the sustainable management of the species in the mountains. Observations found on the ground at Mount Oku at Cameroon found that the bark recovered in three years without reaching the thickness of undeveloped parts (Nkongmeneck *et al.,* 2014). Kourogue (2010) showed that in the North-west and South-west Cameroon, the altitude has no significant effect on the speed of recovery from the bark farm.

Productivity of a rod exploitable

The average dry weight of a rod subjected to research in all operating sites is 33.0 kg. This value was far higher than that found by Betti *et al*. (2013) in Teza the sector in Burundi and those of Ondigui (2001) on Mount Oku and Mount Cameroon as 26.5kg, 27.5kg

and 25kg respectively. The result is consistent with those found by Cunnighan and Mbekum (1993) and then Acworth Ewusi (1999) for which an average adult tree produces between 27.5kg and 35 kg of bark per year respectively.

CONCLUSION

In all sites, altitude has a significant effect on dendrometric parameters such as bark thickness, height and diameter. The barked trees have various reactions due to stress caused by debarking, some remain alive and the other die; especially those with a DBH greater than 80 cm are alive. They regenerate bark at an average annual increase of 1.5 ± 0.6 mm per year. The average dry weight of the usable stem in all operating sites is 33.0 kg but varies with altitude at various operating sites. In the mining sites, the harvest is done according to the standards of sustainability. The bark is used by applying the technique of two opposing quarters following half-rotation of 6 years.

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