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COMPARATIVE POPULATION ECOLOGY OF S*CLEROCARYA BIRREA* (A. RICH.) HOCHST. SUBSPECIES *CAFFRA* (SOND) IN TWO RURAL VILLAGES OF LIMPOPO PROVINCE, SOUTH AFRICA

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Abstract

Sclerocarya birrea (A Rich.) Hochst. subspecies *caffra* (Sond) is a plant species belonging to the Anacardiaceae family. In South Africa, it is dominant in the Baphalaborwa area in the Limpopo Province. Throughout its distribution range, *S. birrea* is a keystone species that is highly utilized by herbivores and people. Understanding the utilization pattern assist in determing if the population is not negatively affected. The aim of this study was therefore to compare the distribution patterns and population status of *S. birrea* in Ga-Makhushane and Tshivhongweni villages in the Limpopo Province. The study will investigate the influence of culture in utilization of *S. birrea* resources since the study area are made up of communities of people from different cultures. Nearest-neighbour method of sampling individuals within a population of plants was used to collect data on *S. birrea* populations which was analyzed using Analysis of Variance. It was found that the populations were regularly distributed meaning there is an antagonistic relationship of the species with the users in both villages, and there was also a significant difference in distribution patterns between the two villages. It was concluded that although *S. birrea* is regularly distributed in both villages, there are differences in terms of interplant distances, heights, stem circumferences and canopy covers. It means that the two culturally different communities have different preferences when they harvest resources form *S. birrea* species.

Key words: *Sclerocarya birrea*, Distribution patterns, Population status, Nearest-neighbour method, Analysis of variance.

Introduction

Sclerocarya birrea (A Rich.) Hochst. subspecies *caffra* (Sond) (Maroyi 2014; Li *et al.,* 2015) formerly known as *Poupartia birrea* (A. Rich.) Aubrév (Gouwakinnou *et al.,* 2009, Hamidou *et al.,* 2014), is a member of the Anacardiaceae family (Maroyi, 2013; Viljoen, Kamatou & Baser, 2008) comprising of 73 genera and 600 species (Viljoen *et al.,* 2008). *S. birrea* is commonly known as marula (Emanuel, Shackleton & Baxter, 2005) or cider tree (English), maroela (Afrikaans), or umganu (Isizulu), morula (Sepedi), mufula (Tshivenda) and nkanyi (Xitsonga) (Ojewole, 2003; Masoko *et al.,* 2008). *Sclerocarya birrea* can be further classified into three subspecies which are; *S. birrea* subsp. *birrea* (A. Rich.), *S. birrea* subsp. *caffra* (Sond.) and *S. birrea* subsp. *multifoliota* (A. Rich.) (Mouk *et al.,* 2007, Nyoka *et al.,* 2014).

It is commonly found in wooded grasslands, riverine woodlands and bushlands (Muok *et al.,* 2007; Kpoviessi *et al.,* 2011). The plant is found in east tropical Africa (Kenya and Tanzania), south tropical Africa (Angola, Malawi, Mozambique, Zambia and Zimbabwe) and southern Africa (Botswana, Namibia, South Africa and Swaziland) and also in other countries outside Africa like Madagascar (Maroyi, 2014). *Sclerocarya birrea* is a highly resilient, fast growing savanna and community-dominant tree species (Helm, Scott, and Witkowski, 2011). In South Africa, it is more dominant in the Ba-phalaborwa area in the Limpopo Province (Kpoviessi *et al.,* 2011), whereas in Malawi this plant species grows mainly in hot dry areas (Mkwezalamba, Munthali, and Missanjo 2015), similar to those of Baophalaborwa.

Sclerocarya birrea grows in well-drained, sandy and loamy soil, but it is in most cases intolerant to frost (Maroyi 2014). Due to its ability to tolerate drought and poor soil (Li *et al.,* 2015), *S. birrea* is capable of growing in areas which receive about 200 mm to 1600 mm of rainfall per year (Mkwezalamba, Munthali, and Missanjo, 2015). Throughout its distribution range, *S. birrea* is a keystone species that is preferred and utilized by both herbivores and people (Helm, Scott, and Witkowski 2011). Propagation is by seeds or vegetatively (Mollel & Goyvaerts, 2012).

Sclerocarya birrea has multifaceted uses which are commercially, medicinally and culturally important in Africa, and has been identified as one of the five fruit tree species which are important for nutritional, health and income security (Gouwakinnou *et al.,* 2011). It is widely used by local communities as a source of food and medicine as well as cultural practices (Mawoza, Ojewole, and Owira, 2012). The use of *S. birrea* and its value varies among various ethnic groups throughout its distribution range in the western Africa (Gouwakinnou *et al.,* 2011). In the Southern Africa, *S. birrea* is considered as one of the most important plants which are becoming commercially important (Leakey, 2005), and it is extensively used in folk medicine for a wide variety of ailments and inflammations (Moyo, Finnie, and Van Staden, 2011); its products have entered the local and international trade (Leakey, 2005). The stem-bark, roots, leaves, fruits and seeds of *S. birrea* possess medicinal, social, and nutritional values. In South Africa, the stem-bark, roots and leaves of this plant are used traditionally to treat human ailments such as infections (malaria, fever, diarrhoea, dysentery, schistomiasis) and digestive diseases (stomach disorders, headaches, toothache, high

blood pressure, backache, dysmenorrhoea, body pains, diabetes mellitus, arthritis) (Mawoza, Ojewole, and Owira, 2012).

The patterns of abundance distribution and population structure are some of the variables which can be used to help deduce key demographic stages or ecological variables that merit special focus when implementing a management scheme (Gouwakinnou *et al.,* 2009). The same authors have indicated that these variables can differ based on the type of habitat, and they should be evaluated for any given species in the multiple habitats in which it occurs given that comparative studies of biodiversity in alternative land-use scenarios are important to inform policy makers about the potential impacts of changes in land use on both conservation and livelihood goals. However, Xu *et al*., (2018), suggest that the adaption of plants to certain environmental conditions is perceived to be represented by the general appearance and growth of plants in such environments. Understanding vegetation pattern and diversity is therefore very much important in the management of biodiversity (Sadia *et al*., 2017).

The aim of this study was to compare the distribution patterns and population statuses of *S. birrea* in Ga-Makhushane and Tshivhongweni villages in the Limpopo Province. Since this plant has gained more attention and is widely used by different communities as also supported by Nghitoolwa, Hall, and Sinclair (2003), a question was raised as to what are the patterns of its distribution in some of the villages where it is highly used. The utilization of this species in production of traditional wine as well as extraction of its oily seed kernels used for different purposes in the two villages makes it necessary to understand its population structures in the two sites. On the other hand more studies focused on the use of *S. birrea* and very little on its distribution patterns and population statuses in the areas where it is found. The gross collection of its seeds might affect the recruitment of its population if it is not well monitored.

Materials and Methods

Study area: The study was conducted in Ga-Makhushane (Ba-phalaborwa Municipality) and Tshivhongweni (Mutale Municipality) in the Limpopo Province. The study areas were selected based on the relative abundance of *S. birrea* individuals. Ga-Makhushane is a small village found in the Ba-phalaborwa Municipality, Mopani District, Limpopo Province. It is situated along the latitude S 23° 57′ 46.00″ and longitude E 31° 2′ 58.00″ (www.mbendi.com). It is situated 2 km from the Namakgale Township (www.mbendi.com). The area receives approximately 360 mm of rain annually, whereby the most rainfall is received during mid-summer (www.saexplorer.co.za). The lowest amount of rainfall which is about 0 mm is received during August whereas the highest amount is about 76 mm and is received during January (www.saexplorer.co.za). Ba-phalaborwa Municipality usually experiences high temperatures in summer with the average of 31°C (www.kokobela.com) and it is mostly cold during July when the temperature drops to 8°C (www.saexplorer.co.za).

On the other hand Tshivhongweni is a small village in the Mutale Municipality, Vhembe District, Limpopo Province, South Africa (www.mbendi.com). The village is situated between latitude S 22° 34′ 10.00″ and longitude E 30° 35′ 50.00″ (www.mbendi.com). Mutale Municipality receives approximately 681 mm of rainfall per year whereby the most rainfall occurs during mid-summer in January which is about 137 mm and the lowest rainfall occurs during winter in July which is about 2 mm (www.saexplorer.co.za). The average midday temperature for Mutale Municipality ranges between 22.1°C in June to 29.2°C in January whereby the coldest time for this region is in July when the temperature is 7.7°C (www.saexplorer.co.za).

Species description: *Sclerocarya birrea* has compound leaves which are 8 to 38 cm long, clustered close to the end of the branches, and they are alternate and imparipinnate (Mokgolodi *et al.,* 2011). The leaflets are ovate to elliptic in shape with a dark green colour above and a light blue-green colour below (Emanuel, Shackleton and Baxter 2005) with smooth margins (Mokgolodi *et al.,* 2011) and a sharp point (Mariod and Abdelwahab 2012). This plant is single stemmed and has grey fissured bark (Fotio *et al.,* 2009). Although *S. birrea* is regarded as primarily dioecious (Mokgolodi *et al.,* 2011) but rarely the plant shows a state of monoecy (Nyoka *et al.,* 2014). This plant ordinarily bears flowers between September and December and the fruits from January to March (Dimo *et al.,* 2007; Mokgolodi *et al.,* 2011; Nyoka *et al.,* 2014). The flowers are usually greeninsh-white or reddish in colour (Dimo *et al.,* 2007) and small with red sepals and yellow petals (Ojewole, 2007). According to Helm, Scott, and Witkowski (2011), *S. birrea* is an entomophilous plant and its major pollinator is the honeybee. *S. birrea* plant bears pale green plum sized fruits which grow up to 3-4 cm in diameter with a plain tough peel and fibrous juicy mucilaginous flesh (Hillman, Mizrahi, and Beit-Yannai 2008) which has a sweet-sour and a high aroma (Hiwilepo-van Hal *et al.,* 2014). The seeds of *S. birrea* contain about two to three edible kernels, although the number of kernels per seed differs from zero to four within fruits of the same tree (Mokgolodi *et al.,* 2011). These seed kernels are rich in oils and proteins (Vermaak *et al.,* 2011). According to Midgley, Gallaher, and Kruger (2012), the marula fruit has a tough lignified endocarp or a stone containing a number of seeds whereby each seed is in its own locule sealed by operculum. The operculum limits the germination of the seeds by preventing oxygen from reaching the seeds (Setlalekgomo & Setlalekgomo, 2013). Amongst others; people, elephants (*Loxodonta africana*) and kudu (*Tragelaphus strepsiceros*) are responsible for predation, dispersal and germination of the seeds of *Sclerocarya birrea* (Midgley, Gallaher, and Kruger, 2012; Setlalekgomo & Setlalekgomo, 2013). In natural environment, *S. birrea* is tap rooted which allows it to explore the deeper layers of the soil and limit the constraints of competition drought (Hamidou *et al.,* 2014).

Data collection and statistical analysis: Utilization data of *Sclerocarya birrea* was collected through interviews that were conducted in the two villages of Ga-Makhushane and Tshivhongweni. In each village 35 homesteads were selected randomly and before the interviews could start with the people, a brief explanation was given to them on what the study was all. Prior informed consent was obtained from each informants who were also given the right to withdraw at any time if whenever they felt not comfortable with the interviews.

Nearest neighbour method (Clark & Evans, 1954) was used to determine the distribution pattern of *S. birrea* in the selected areas. Plant species outside the homesteads but within the same village were selected randomly and the distances between the two nearest neighbour individuals were measured. Their circumferences, heights and canopy covers were also measured. The circumferences were measured using a measuring tape at 1.3 m above the ground, the heights of the plant individuals were measured through the use of a height meter rod placing it next to the tree. Estimations of the tree height were made based on the length of the height meter rod. In order to get the size of the canopy cover, two people with one standing at one end of the canopy and another one at the other end of the canopy extended the tape and recorded the length of the canopy. Two measures per canopy were taken and then averaged. The measurements were used to estimate whether tree individuals are distributed in a random, regular or clumped manner and also whether the use of marula products is correlated with their distribution pattern or with the sizes of individuals.

The Analysis of Variance (ANOVA) single factor, was used to compare if there are any significant differences between the canopy covers, heights and stem circumferences of the plant populations amongst the two villages. To determine the distribution pattern of *S. birrea* in the two villages visited, a method applied by Clark and Evans (1954) was employed. The distribution ratio $R = (\bar{r}A)/(\bar{r}E)$ was used to determine whether plant individuals were randomly, regularly and clumpishly distributed. Where $\bar{r}A$ is the mean of the series of distance to the nearest neighbour and $\bar{r}E$ is the mean distance to nearest neighbour expected in an infinitely large random distribution of density. The density was calculated as the number of individuals per unit area. The distribution ratio is equal to the mean or average distance between the *S. birrea* trees divided by half the square root of the total number of the trees as repeated by the formula. If R is equal to 1 the population is randomly distributed, if R is greater than 1 the population is regularly, and if R is less than 1 the population is clumpish in distributed. ANOVA was again used to determine if there are any significant differences among the distances between tree population individuals in both villages.

Results

General view on the importance of *S. birrea* at Ga-Makhushane village and Tshivhongweni village: Participants from Ga-Makhushane village generally regarded *S. birrea* as an important tree in their livelihoods. Seventy three percent of the participants use it as a source of food, 14% using it for medicinal purposes, and only 2% using it for ritual purposes (spiritually connecting with the ancestors). The pattern was almost the same at Tshivhongweni village where the plant is reported to be used as a source of food (70%), medicine (25%), shade (4%), and also as a wind breaker (1%).

Figure 1 shows the comparison between the Bapedi (Ga-Makhushane) and the Vhavenda (Tshivhongweni) in terms of number of uses and preferred parts of *S. birrea*. Bapedi have a higher number of uses for fruits and stem than Vhavenda, whereas Vhavenda have higher number of uses for bark than Bapedi. Both cultures have an equal number of uses for the leaves and roots. In both cultures, the fruits have the highest number of uses (n = 21 and 16 respectively). Amongst Bapedi cultural group, bark and stem have an equal number of uses (n = 7) whereas leaves and roots have the lowest number of uses (n = 5).

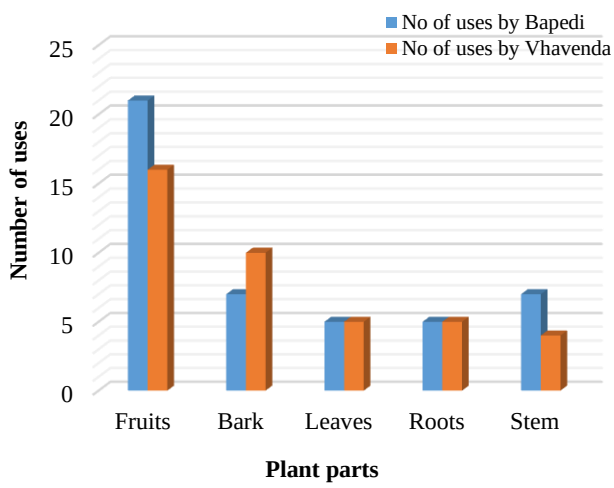

Fig. 1. The comparison of the number of uses of S. birrea between the Bapedi and the Vhavenda cultural groups.

Distribution of *Sclerocarya birrea*: The distribution patterns of *S. birrea* populations in Tshivhongweni and Ga-Makhushane villages were found to be regular with distribution ratio (R) of 1.14 and 1.81 respectively. Although the distribution ratios of the two villages showed that the populations were regularly distributed, statistical results showed that there was a significant difference between the distances of *S. birrea* individuals in the two villages of Tshivhongweni and Ga-Makhushane ($p<0.05$) (Table 1).

Population status of *S. birrea* in the two villages: The results in figure 2 showed that the *S. birrea* tree individual species growing at Ga-Makhushane village were taller than those growing at the Tshivhongweni village with the average heights 10.33 m and 7.72 m respectively. There was a significant difference between the heights of the tree individuals between the two villages since $p<0.05$ (Table 2).

As shown in figure 3 the circumferences of the tree individuals found at the Tshivhongweni village were larger than those of the tree individuals found at Ga-Makhushane village with the averages of 3.78 m and 1.86 m respectively. There was a significant difference in the circumferences between the two villages since $p<0.05$ (Table 3).

Table 1. A summary of the statistical analysis of the distances between *S. birrea* individuals of Ga-Makhushane and Tshivhongweni villages.

Villages	Count	Sum	Average	Variance	F	p
Ga-Makhushane	67	730.7	10.90	17.40	28.67	<0.05**
Tshivhongweni	73	477.8	6.54	28.45		

** = Highly significant

Table2. A summary of the statistical comparison of the tree heights of *S. birrea* in Ga-Makhushane and Tshivhongweni villages.

Villages	Count	Sum	Average	Variance	F	p
Ga-Makhushane	50	516.7	10.33	7.68	22.60	< 0.05**
Tshivhongweni	50	386.1	7.72	7.41		

** = Highly significant

Table 3. A summary of the statistical comparison of stem circumferences of *S. birrea* plant individuals in Tshivhongweni and Ga-Makhushane villages.

Villages	Count	Sum	Average	Variance	F	p
Ga-Makhushane	50	92.8	1.86	1.63	48.54	< 0.05**
Tshivhongweni	50	189.15	3.78	2.19		

** = Highly significant

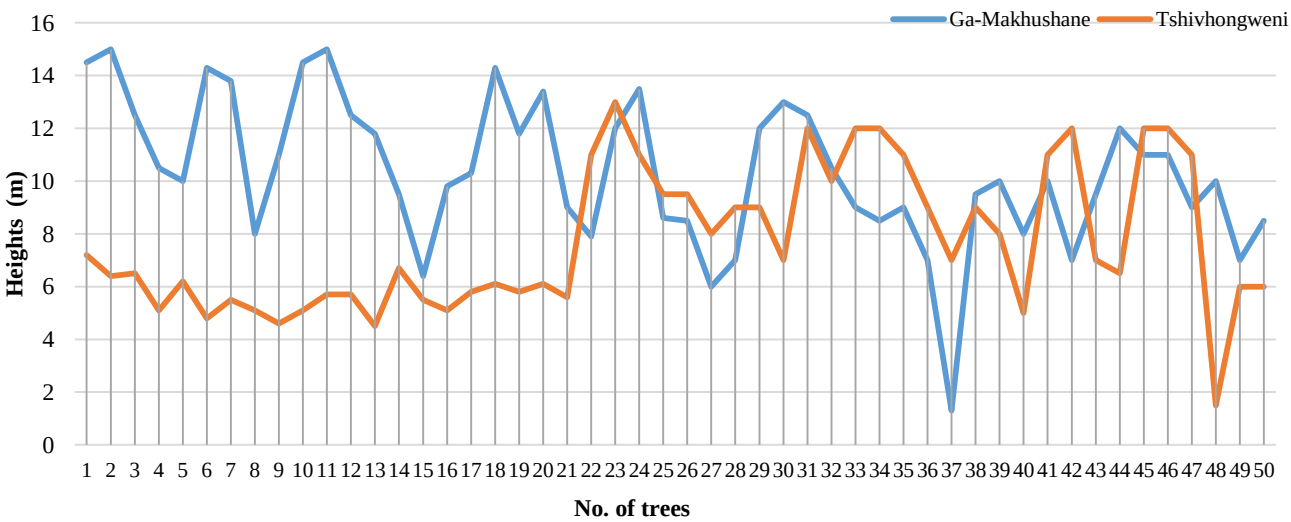

Fig. 2. Comparison of heights of *S. birrea* in Tshivhongweni and Ga-Makhushane village.

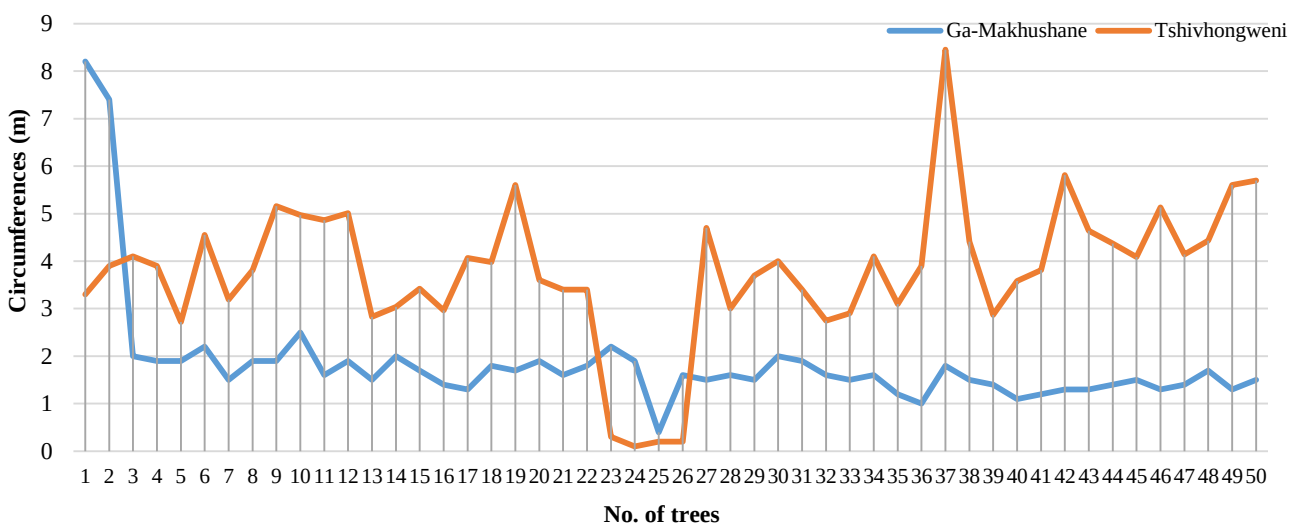

Fig. 3. The comparison of the circumferences of the stems of *S. birrea* individuals between Ga-Makhushane and Tshivhongweni villages.

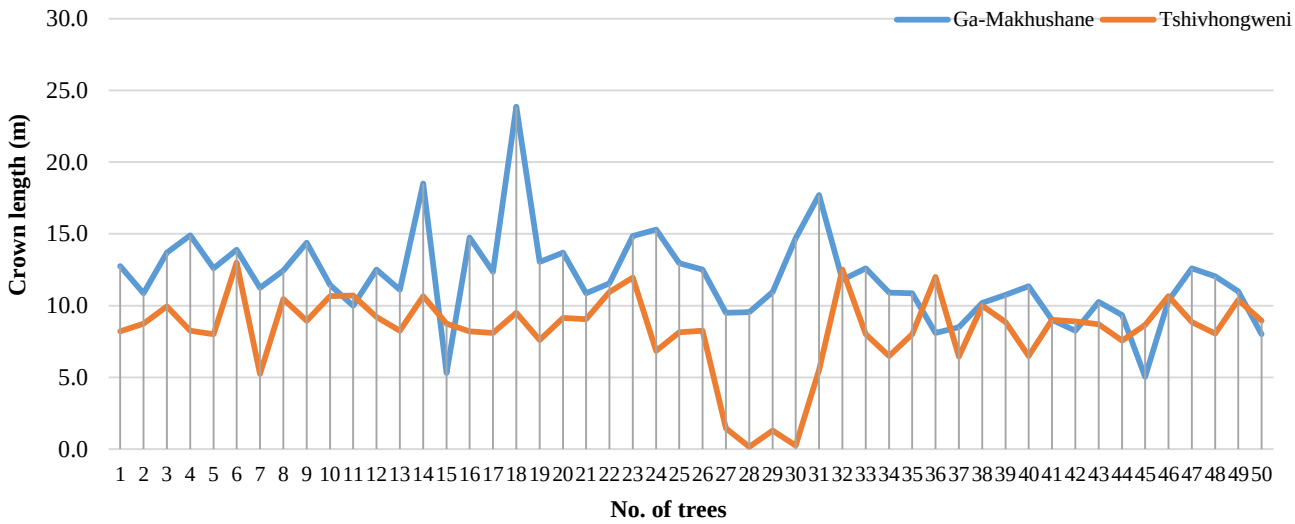

Fig. 4. The comparison of the canopy covers of *S. birrea* plant species between Ga-Makhushane and Tshivhongweni village.

Table 4. The statistical comparison of the canopy covers of S. birrea plant individuals between Ga-Makhushane and Tshivhongweni villages.

Villages	Count	Sum	Average	Variance	F	p
Ga-Makhushane	50	594.68	11.89	9.79	37.47	< 0.05**
Tshivhongweni	50	413.90	8.28	7.65		

****** = Highly significance

Figure 4 shows the canopy covers of the trees found at Ga-Makhushane village to be broader than the canopy covers of those found at the Tshivhongweni village with the average size of 11.89 m and 8.28 m respectively. The canopy covers of the two villages differed significantly since $p<0.05$ (Table 4).

Discussion

General view on the importance of *S. birrea* at Ga-Makhushane village and Tshivhongweni village: *Sclerocarya birrea* is an interesting plant to deal with particularly when one looks at its importance to the different kinds of cultures and communities. One has to bear in mind that it is considered as the tree of life (Komane *et al.*, 2015 and Maroyi, 2013) due to its wide variety of uses. In both cultures the participants indicated that the tree is mostly important as a source of food with 73% of the participants from Ga-Makhushane village and 70% of the participants from Tshivhongweni village. This could basically be due to public knowledge about the general uses of *S. birrea* fruits because they are readily available during their season which is generally from December to early February.

This study also revealed that different parts of the plants are preferred for different purposes. It is evident that fruits of *S. birrea* are the ones which are mostly preferred by the participants in both cultures. Similar results were reported by Maroyi (2013), in a study conducted in South-Central Zimbabwe which reported that consumption of S. birrea fruits plays a vital role in diets, culture and income generation of the local people. The study found the species to be reducing poverty amongst poor people. At Ga-Makhushane village fruits are used in making juice which is given to children before it ferments. Once fermented into wine it can only be enjoyed by adults. The marula wine is therefore used in income generation. This beer is also drank during different kinds of gatherings and for other cultural gatherings. Hiwilepo-van Hal *et al.*, (2014) indicated in their study that the marula wine is produced in many parts of South Africa, hence almost every participant reported the fruits to be used for making marula wine.

Distribution of *Sclerocarya birrea:* The results show that in both villages (Ga-Makhushane and Tshivhongweni) the plant population of *S. birrea* was regularly distributed and this was probably due to the location of the study areas. The areas are semi-arid which result in limited nutrients and water availability thereby rendering the population regularly distributed. According to Li *et al.*, (2015), *S. birrea* is drought resistant, capable of growing in dry and hot conditions and also in poor soils and this gives them the ability to survive than other plant species in those areas. Notwithstanding the harsh conditions of the two areas, the individuals of this plant species are tap rooted and such allow them to explore the deeper layers of the soils and minimize the constraints of competition and drought (Hamidou *et al.*, 2014). It is therefore not puzzling to find them doing well at places such as Ga-Makhushane and Tshivhongweni which are semi-arid sandy hot areas during summer periods.

The distribution pattern of these plants can also be associated with their medicinal, cultural and economic importance to the people in those areas since the people are therefore somehow using the plant for different purposes. Although these plants are distributed in a regular pattern in these places, the results also show that

there are significant differences (p<0.05) in terms the distances between their individuals with the average distances being 6.8 m at Tshivhongweni and 23.2 m at Ga-Makhushane. This could possibly be ascribed to the already stated environmental factors and inter- and/or intra-specific competition. Gouwakinnou *et al.,* (2009), reported that factors such as pattern of use and harvest, land use type and level of intra and interspecific competition are susceptible to affect size class distribution of a given species. Competition causes stress between and within plant species and is essential for determining the distribution patterns of plant species (Craine and Dybzinski 2013). For instance in both villages, plants were scantily distributed, a possible reinforcement of harsh conditions effects on plant life.

Population status of *S. birrea* in the two villages: The individuals of *S. birrea* population at Ga-Makhushane village were taller than those of Tshivhongweni village (Fig. 2). This is ascribable to factors such as temperature, soil type and soil moisture variation. Gouwakinnou *et al.,* (2009) found that there was a difference in population structure of the species according to land use. The denseness of plant species and hence competition for resources may be another cause of physical differences between similar individual species of the two areas. Mucina and Rutherford (2011), explained the vegetation at Ga-Makhushane to be composed of tall trees such as *Acacia nigrescens*, *Sclerocarya birrea* subsp. *caffra*; short trees such as *Colophospermum mopane*, *Combretum apiculatum*, *Terminalia sericea* amongst others; tall shrubs such as *Combretum hereroense*, *Euclea divinorum*; low shrubs such as *Clerodendrum ternatum*, *Commiphora africana*; woody climber *Cissus cornifolia*, Graminoids: *Digitaria eriantha* subsp. *pentzii*, *Eragrostis rigidior* and herbs such as *Evolvus alsinoides*, *Heliotropium stuedneri*. On the other hand the same authors indicated that the Tshivhongweni is composed of tall tree such as *Acacia nigrescens*, *Adansonia digitata*, *Sclerocarya birrea* subsp. *caffra*, *Colophospermum mopane*, *Combretum apiculatum*; tall shrubs such as *Grewia flava*, *Sesamothamnus lugardii*; short shrubs such as *Acalypha indica*, *Aptosimum lineare*, succulent shrub such as *Hoodia currorii* subsp. *lugardii* and herbaceous climber such as *Momordica balsamina* and Graminoids such *Schmidtia pappophoroides*.

The results also showed that stem circumferences of the plant population at Tshivhongweni village were bigger than those of Ga-Makhushane village (Fig. 3). Shackleton, Botha, and Emanuel (2003), in their study also found that the mean stem circumference of *S. birrea* in the villages were significantly larger than those in the protected area. Canopy covers of *S. birrea* at Ga-Makhushane village were broader than those at Tshivhongweni village which might be due to environmental conditions which facilitate growth and subsequent development of plant. Holdo, Mack, and Arnold (2012), showed that canopy cover is highly associated with the amount of nutrients and carbon pool in the soil. On the other hand the smaller canopy covers might imply less supply of nutrients from the soil and hence, reduction in the chances of canopy expansion.

Conclusions

The results showed that the plant populations in both study sites were regularly distributed which is associated environmental factors and associated competitions. Although these plant populations are regularly distributed there are differences in terms of interplant distances, heights, stem circumferences and canopy covers which are influenced by the locations of the study areas, and hence their edaphic factors.

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