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Growth and fruit production of *Sclerocarya birrea* in the South African lowveld

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Abstract

Sclerocarya birrea (A.Rich.) Hochst. *subsp. caffra* (Sond.) Kokwaro. is a common species throughout the semiarid, deciduous savannas of much of sub-Saharan Africa. It is a favoured species and is frequently maintained in homestead plots and arable fields in an agroforestry situation. Although the abundance and popularity of this species has led to several initiatives to commercialise a number of marula products, the sustainability of the resource base with respect to fruit production has not been considered. This paper reports on a field experiment that monitored growth rates and fruit production of a sample of adult trees from several wild populations. Mean fruit production was 36.8 kg per tree in the first year, and negligible in the second. This was considerably less than previous estimates, which were based largely on small samples or anecdotal reports. The maximum recorded yield was 416.6 kg per tree. Fruit production was positively related to the size of the tree. Growth rates of adult trees were slow. There was a strong positive relationship between mean annual diameter increment and stem diameter. The slow growth rates and low fruit yields indicate that more attention is required regarding the sustainability of the resource and its ability to provide sufficient fruit for the growing subsistence and commercial demand at both local and national scales.

Introduction

Sclerocarya birrea (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro. is a common and widespread species throughout the semiarid, deciduous savannas of much of sub-Saharan Africa (Peters 1988). It is frequently a community dominant and hence is a keystone species in community ecology and productivity. It is browsed by wild game and domestic livestock (Palmer and Pitman 1972) and is the preferred host species for a number of parasitic plants (Dzerefos 1996) and larvae of several invertebrates (Kroon 1999).

Sclerocarya birrea is not only important as a dominant tree species in plant communities, but it is also widely used by rural populations in most countries in which it is found (Palmer and Pitman 1972; Shone 1979; Walker 1989; Shackleton et al. 2000). It has multiple uses, including the fruits which are eaten fresh or fermented to make a beer, the kernels are eaten or the oil extracted, the leaves are browsed by livestock and have medicinal uses, as does the bark. The wood is carved into utilitarian items such as spoons and plates as well as decorative animal figures. Because of these multiple uses, and its significance in the landscape, several African cultures have specific beliefs and ceremonies associated with this species (Walker 1989). A significant proportion of households nurture seedlings of *S. birrea* that germinate in the grounds of their homestead or arable fields, and maintain adult trees in an agroforestry situation (High and Shackleton 2000; Shackleton et al. 2000). Others plant seedlings or propagate trees via stem cuttings. In the wild, germination is improved after passage of the fruit through the digestive tract of certain animal species, especially elephant (Lewis 1987).

Because of the widespread occurrence and use of *S. birrea* it has frequently been identified as a desirable species to support the development of rural enterprises based on the fruit, beer, or nuts and therefore as a species for potential domestication (Taylor and Moss 1983; Holtzhausen et al. 1990; Nerd and Mizrahi 1993; Leakey and Simons 1998). Localised breeding and cultivation initiatives commenced in the 1970s and some continue. Interest in this species was renewed after the development of a highly successful liqueur using extracts from the fruit. This has developed further in southern Africa over the last 3 to 5 years, especially commercialisation initiatives orientated towards benefitting the rural poor, including initiatives in Botswana, Namibia and South Africa (e.g. Taylor and Moss (1983) and Maree and Doyer (2001)).

Despite the accelerating interest in commercialisation prospects for *S. birrea* fruits, the data on rates of fruit production from wild populations remains scanty; much of it being anecdotal. Many are casual observations or records of one or two accessible trees, and do not represent a good sample from wild populations. Quin (1959) measured fruit yield from four trees at Zebedelia estate in Northern Province (South Africa) that produced between 21,667 and 91,272 fruits each in the 1951/52 season, with an average yield of 550 kg. In comparison, Shone (1979) reported on one tree from the same area as producing 9,601 fruits or 270 kg. In the drier areas of western Northern Province, and Botswana, Peters (1988) reported a yield of 2,000 fruits (one tree) and 36,550 fruits or 550 kg per tree (11 trees), respectively. Lewis (1987) measured fruit yield over a single month from 111 trees in the Luangwa valley (Zambia), and reported a total 226,000 fruits, or just over 2,000 fruits per tree. A figure of approximately 70,000 fruits per tree, or 570 kg is provided by Roodt (1988). Walker (1989) reported a yield of 6,900 to 12,100 fruits per year from a single tree over five years from the Matobos in Zimbabwe. Holtzhausen et al. (1990) provide a figure of an average of one ton of fruit per tree. The ratio of number of fruits to mass of fruits differs widely between these reports, indicating either extremely wide differences in the mass of individual fruits, or relatively crude extrapolations of mass. Other than that of Lewis (1987), none of the reports purport to be replicable scientific studies, and methods are not presented.

The growing number of commercialisation initiatives based on scanty fruit production data should be cause for concern. The encouragement of small or large-scale enterprises is dependent upon there being adequate resources to supply the commercialisation drives. If there are inadequate resources, then the stability of *S. birrea* populations and the commercial enterprises will be jeopardised to the detriment of both, and ultimately the rural populations that have used the resource for millennia. This lack of information relates not only to fruit production, but also densities of adult trees in wild populations, size-structure profiles and tree growth rates. Consequently, this paper reports on two studies, one that quantified the fruit production of *S. birrea* in the South African central lowveld over two growing seasons, and another monitoring the growth of mature stems over five years.

Study area

Three protected areas (Hoedspruit Nature Reserve, Wits Rural Facility, Bushbuckridge Nature Reserve) were identified along a rainfall gradient in the central lowveld (31° 0′ – 31° 35′ E; 24° 30′ – 25° 0′ S), South Africa. For convenience the three localities are termed the arid, semiarid and mesic sites.

All three localities are situated on weathered granites with occasional doleritic intrusions. Altitude is approximately 550 m a.s.l. Typical soil catenal sequences are evident throughout the region. Hence, upland soils on slope crests are shallow, coarse and dystrophic, whilst bottomland soils are deeper, finer-textured and more eutrophic. Mean annual rainfall is the primary variable differentiating the three localities, being 484 ± 32 mm at the arid site (Hoedspruit Nature Reserve), 651 ± 123 mm at the semiarid site (Wits Rural Facility) and greater than 870 mm at the mesic site (Bushbuckridge Nature Reserve). At all localities the rainfall is concentrated into the summer season from October to May, and is mostly delivered in the form of convectional thundershowers.

The three localities fall into (Acocks 1988) broad vegetation type of Tropical Bush and Savanna. More specifically, the arid locality is classified as Arid Lowveld dominated by members of Mimosaceae (especially *Acacia nigrescens, A. gerrardii, Albiza harveyii* and *Dichrostachys cinerea*) along with *Combretum apiculatum, Sclerocarya birrea* and *Grewia* spp. The semiarid locality straddles the boundary between the Arid Lowveld and Lowveld vegetation types. The woody stratum is dominated by Combretaceae species (including *Terminalia sericea, Combretum colli-*

num, and *C. hereroense*) with *S. birrea*, and *D. cinerea*. The mesic locality is situated on the boundary between the Lowveld and Lowveld Sour Bushveld types dominated by more broad-leafed species such as *Pterocarpus angolensis, Faurea saligna, T. sericea, C. collinum, and Parinari curatellifolia* along with *S. birrea* and *D. cinerea*. Species basal areas, densities and biomass are provided by Shackleton (1997).

Sites for the tree growth study were scattered throughout the South African savanna biome across a range of altitudes, rainfall, and soil types (Shackleton 1997).

Monthly rainfall records at the semiarid site indicated that the rainfall received from the beginning of the rainy season to the end of the fruiting period (August to February) was 397 mm in 1993/94 and 390 in 1994/95. The total seasonal rainfall (August to May) for 1992/93 (the year preceding the fruit production study) was 838 mm, for 1993/94 it was 494, and in 1994/95 is was 505. Thus, total seasonal rainfall for both years of this study was 20 to 25% below the long term mean.

Methods

Fruit production

In November 1993 64 trees distributed within the three study sites were permanently marked. They were visited every five to seven days and all fruits on the ground were counted. This was continued until no more fruits were found. Every fiftieth fruit was collected and fresh mass determined. These were dried at 80°C for five days to determine dry mass. This was repeated in the subsequent growing season for the same trees. Height and basal circumference of the trees were measured.

Tree growth rates

In August 1992, 52 permanent plots were established throughout the South African savanna biome to quantify the annual increment of trees and shrubs (Shackleton 1997). Each tree in each plot was marked with a painted line 30 cm above ground level. Stem circumference was measured above this line. Trees were measured annually in August for five years. *S. birrea* was present in 20 of these plots, with a total of 44 trees.

Results

Fruit production

During the 1994/95 season most trees did not bear fruit; the few that did had only very few fruits, and hence were not recorded. The mean mass of fruit at each locality during 1993/94 ranged from 21 kg to 56 kg per tree, with a mean across all three sites of 36.8 ± 7.8 kg per tree (Table 1). The maximum recorded was 416.6 kg, and the minium was less than 1 kg, just a few fruits.

During the 1993/94 season, the amount of fruit produced was positively related to size of the tree. Separate relationships were derived for each locality (Table 2).

Tree growth rates

There was a strong positive relationship ($r^2 = 0.206$; $p < 0.01$; n = 44) between mean annual diameter increment and stem diameter (Figure 1). This was summarised in the form:

$$\textit{Annual diameter increment (mm)} = -0.068(\textit{basal diameter})\ (\textit{cm}) + 4.54$$

Thus, a 15 cm diameter tree had a mean diameter increment of approximately 3.5 mm per year. A tree of 30 cm diameter had a mean annual increment of 2.5 mm per year. On this basis, a 1.5 cm diameter recruit would take 35 years to reach 15 cm diameter, or 85 years to attain a diameter of 30 cm. The smallest tree in the fruit production experiment was 9 cm in diameter. This corresponds to an age of 18 years. This is probably an overestimate of the age since the trees in the sample for growth rates were all large, and therefore reflect rates for adult trees, and excludes the sapling stage, which typically have higher growth rates.

Discussion

The mean fresh mass of fruit per tree (across a range of tree sizes and environments) was less than 40 kg. This is an order of magnitude less than previous estimates from a few isolated trees. This may be a result of (i) previous estimates being from exceptionally large or productive trees, (ii) the trees were situated in altered environments (such as gardens with more

Table 1. Fruit production by 64 marked *S. birrea* trees in 1993/94 at three localities in the central lowveld, South Africa

Attribute		Locality			Mean across all localities
		Arid (n = 30)	Semiarid (n = 22)	Mesic (n = 12)	
Circumference of marked trees (cm)	Mean	114.3 ± 5.49	135.5 ± 12.51	134.0 ± 17.70	125.3 ± 6.03
	Range	70.2–163.5	29.5–239.1	56.7–230.1	56.7–39.1
Number of fruit produced	Mean	933 ± 207	2,772 ± 865	1,937 ± 603	1,753 ± 343
	Range	21–4,831	25–16,170	34–4,992	21–16,170
Mean fresh mass of a subsample of individual fruits (g)	Mean	23.2 ± 1.05	19.1 ± 0.86	18. 0 ± 1.06	20.6 ± 0.70
	Range	13.9–37.3	14.0–27.1	10.9–23.8	10.9–37.3
Fresh mass of fruit per tree (kg)	Mean	23.7 ± 6.04	55.9 ± 19.87	34.3 ± 10.53	36.8 ± 7.75
	Range	0.4–143.4	0.5–416.6	0.3–58.7	0.4–410.7

Table 2. Relationships between dry mass of fruits produced and tree basal area at three localities in the central lowveld, South Africa

Locality	MAR (mm)	Relationship	Significance		
			r^2	p	n
Arid	500	log(fruit dry mass) (g) = 0.00036(basal area) + 3.12	0.14	$p < 0.05$	30
Semiarid	670	fruit dry mass (g) = 12.1(basal area) − 4,513	0.36	$p < 0.05$	22
Mesic	> 850	fruit dry mass (g) = 6.48(basal area) + 994	0.46	$p < 0.05$	12

Note: Mean moisture content was 65.3%.

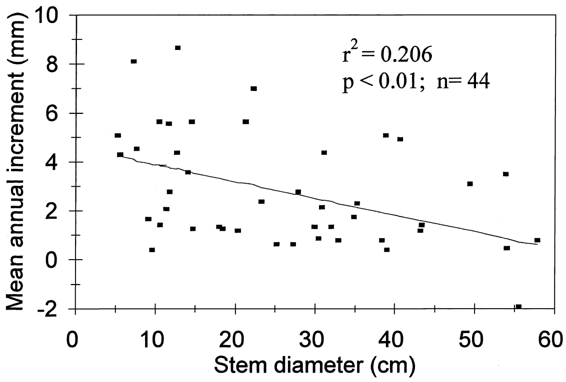

Figure 1. Mean annual increment of *S. birrea* relative to stem diameter

space and water) rather than the natural environment, (iii) they were conducted during an above average season, or (iv) the low rainfall during this study resulted in low fruit yields. Given the largely anecdotal reports from previous work, it is not possible to examine data whether or not possibilities (i) to (iii) are credible. In terms of this study, although the seasonal rainfall was below the long term mean, it was similar for both years, including the totals for the entire rainy season, as well as precipitation received solely during the fruiting period. Therefore, the wide variation in fruit production between the two fruiting seasons cannot be explained by differences in rainfall during the full growing season, or just the fruiting period. However, the rainfall in the season prior to the study was well above average (29% more). If fruiting success was related to soil moisture carried over from the preceding rainy season, such a pattern would explain the difference in fruit production between the two years of this study. Thus, the rainy season preceding the first year of monitoring was good, and so was fruiting in the following year. Rainfall in the season preceding the second year of monitoring was below average, and fruiting in the following year was very low. This hypothesis needs to be examined with longer term monitoring (5 to 10 years) of marked trees and their fruit yield. Rutherford (1984) proposed that tree growth in semiarid savannas was rather related to storage of water carried over from the previous season, rather than the current season.

Recent data from Todd (2001) provided a mean yield of 17.4 kg per tree from 122 trees across several localities for the 1999/2000 season. In 2000/2001 she remeasured 40 of these trees, and recorded a mean yield of 4.3 kg per tree. Such a wide inter-annual variation in the production of fruits represents a challenge to a sustainable commercialisation initiatives, as has been commented on for other non-timber forest products (Boffa et al. 1996). The approach used by Todd (2001) was to count fruits on the ground and on the tree at a single visit at the height of the season. She notes that it was possible for some fruit to have been removed by people or animals before the count was performed. Thus, the mean yields recorded by her are underestimates. Nevertheless, the results from her study and this one indicate that mean fruit yields per tree from a large sample drawn from wild populations comprising a range of tree sizes is probably less than 40 kg per tree, but a few trees are capable of producing ten or more times this.

With densities of adult, female trees being approximately 4 to 6 per hectare (assuming a sex ratio of 1:1), (Shackleton 1996; Lombard et al. 2000) this gives an approximate fruit yield of 150 to 300 kg per hectare. Given the wide distribution of *S. birrea* this is more than enough to support national demand for current and growing commercialisation initiatives. Holtzhausen et al. (1990) reported that the major formal industry using marula uses approximately 2,000 tons annually. At a more localised level this may not be the case, especially with concurrent high demand from rural households (Shackleton et al. 2000). Thus, it is desirable that commercialisation initiatives implement monitoring systems for tree density and recruitment.

Lombard et al. (2000) stated that harvesting of fruit from *S. birrea* would not pose any direct environmental risk. However, this needs a focussed study, especially since yields per tree are probably less than have previously been believed. Even with high fruit yields, harvesting of the fruit for human use may indirectly impact on the potential regeneration of the species. Case studies with other species also with an apparent abundance of fruits, have indicated declines in recruitment and altered size structure profiles over the long-term in the face of increased harvesting by humans (e.g. Boot and Gullison (1995) and Peters (1999)), not to mention the impacts on populations of other species that utilised the fruits or browse the seedlings. However, some species seem able to withstand heavy, sustained harvesting of fruits. For example, Bernal (1998) indicated that populations of *Phytelephas seemannii* could tolerate an 86% harvest of fruits. The fact that *S. birrea* has been harvested for millennia and yet remains a dominant species suggests it too is able to tolerate at least a fair degree of harvesting. However, precisely what is a sustainable yield requires investigation, especially in the face of growing demand from commercial initiatives. The fact that *S. birrea* germinates readily and can also be propagated via stem cuttings means that it should be possible to readily replace stocks if fruit harvesting reduces recruitment in the long term. However, it is necessary that an 'early-warning' system is in place to detect such potential shifts and implement appropriate interventions before fruit supplies are reduced, with negative impacts on local rural livelihoods and incomes. This is particularly so with respect to increasing commercialisation since large volumes of fruits are removed from the environment and either used entirely, or the nuts discarded at a single location. In contrast, during subsistence use, the same number of fruits may be collected from the environment, but these are not concentrated in one location but amongst many households, and after the fruit is consumed the seeds are discarded throughout the landscape, or a proportion retained and the nuts extracted. Indeed, unpublished data from Mozambique and KwaZulu-Natal Province in South Africa indicate that densities of *S. birrea* are greater in anthropogenic landscapes than adjacent rangelands (A.B. Cunningham (WWF/People and Plants Initiative), Sept 2001, pers. communication). In areas where increasing commercialisation is occurring or envisaged, it is necessary to (i) implement a simple and replicable monitoring system of plant densities, recruitment and size profile, and (ii) a rational harvesting strategy that ensures an acceptable proportion of fruits remain unharvested each year as a means of promoting recruitment. Such unharvested fruits are also available for other vertebrates and invertebrate species that make use of marula fruits. Such a monitoring system should be able to differentiate the potentially different causes of any perceived decline, e.g. to insufficient recruitment, chopping of trees for carving wood, or clearance of land for other purposes.

This study has shown that growth rates and fruit production of *S. birrea* are low, well below most of the currently cited figures. This poses particular challenges to cultivation and domestication as demand from commercialisation initiatives increase, especially at a local scale. Appropriate, community-based monitoring systems need to be implemented to detect significant changes in the resource base in these regions.

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