Growth of *Aloe ferox* Mill. at selected sites in the Makana region of the Eastern Cape

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Abstract

There is widespread harvesting of the leaves of *Aloe ferox* to supply bitters and gel for cosmetic and health products. Government and private agencies are interested in expanding the industry as a means of providing income for poor rural communities. With the growing interest in the commercial use of *A. ferox* it is important that harvesting programmes are based on an adequate understanding of the ecology and productivity of the species, which will underpin estimates of possible sustainable yields. In this paper we report mean annual growth rates of 283 *A. ferox* plants (at six sites) during the 2005/2006 season. Growth was variable across sites and plant height. In terms of sites, the mean height growth ranged between 1.7 cm per plant per year at site 4 and 4.6 cm at site 2. The mean height increment across all sites and plants was 2.8 ± 0.2 cm. Plant height had a strong effect on annual increment with small plants (< 6 cm) more than doubling their height in the 12 month period, whereas plants taller than 2 m grew by approximately 1% over the year. Across the five unburnt sites, the mean standing stock of leaves grew by two per plant. The proportion of plants flowering increased progressively with plant height. Most (90%) of the plants that flowered in 2005 did so again in 2006.

Introduction

It has been long appreciated, both internationally and within South Africa, that biodiversity offers numerous benefits to adjacent communities and society at large (Wollenberg and Ingles, 1998, Oksanen et al., 2003 and Lawes et al., 2004). Such benefits include consumptive resources, spiritual and aesthetic needs, employment, and ecological services such as carbon sequestration and water regulation. However, the majority of biodiversity and exploited wild species are located within rural areas, typically underdeveloped in terms of infrastructure, government services, markets and jobs. Consequently, harvesting of wild plants and animals is frequently an important economic activity in these rural areas, and is posited as a potential key player in rural poverty alleviation or mitigation, although this has been questioned by some international commentators (Wunder, 2001 and Angelsen and Wunder, 2003). However, both economic and ecological conditions in South Africa perhaps enhance the potential contributions of wild resource harvesting and trade to lowering the impacts of poverty relative to more tropical areas (Shackleton, 2005 and Shackleton et al., 2007).

Despite thousands of commercial products across the globe from wild species, typically much harvesting of wild plant resources for commercial purposes is done with little or no knowledge of the sustainable harvesting levels of the resource in question (Peters, 1999, Ticktin, 2004 and Emanuel et al., 2005). Indeed, the lack of a basic understanding of the ecology of the harvested species, and the absence of production and yield data is one of the greatest challenges to the development of viable and sustainable enterprises (Neumann and Hirsch, 2000, Cunningham, 2001 and Uma Shaanker et al., 2004) and hence reduced livelihood vulnerability of the rural poor.

One such resource is *Aloe ferox* Mill., a species that has been harvested for its sap (known as bitters) for almost 250 years (Newton and Vaughan, 1996 and Van Wyk and Smith, 1996). Although it has a wide distribution in South Africa, it is largely concentrated in the Eastern and Western Cape provinces (from Swellendam in the west to Howick in the east, a linear distance of over 1000 km). Whilst the commercial market for *Aloe* bitters accounts for most of the harvesting effort, there is local subsistence use of the species for medicinal (Sachedina and Bodeker, 1999), veterinary (Dold and Cocks, 2001) and nutritional (Van Wyk and Gericke, 2000) purposes, pre-dating the arrival of European colonists (Van Wyk and Gericke, 2000). The bulk of the commercial harvesting is for the export market to Europe and North America (Sachedina and Bodeker, 1999), where the bitters is used in the cosmetic and health tonic industries. Nevertheless, there is a growing domestic market. More recently a market has developed for *Aloe* gel, in which the leaves are sent to a local factory where they are macerated and strained to produce a gel, which is then sold in dried form (Newton and Vaughan, 1996).

The seminal work of Newton and Vaughan (1996) provided the first examination of the stakeholders involved in the *Aloe ferox* industries in South Africa and the distribution of benefits between them. They estimated that in 1996 the value of the *Aloe ferox* industry to rural harvesters alone was R4 million per year from producing 400–700 tons of bitters, equivalent to R8–9 million in today's terms assuming no growth of the industry. Given that there has been growth, its worth to small-scale rural harvesters is now in the region of R12–15 million per year. Mark up through the retail chain means that the value of the total industry in South Africa would probably be close to R150 million per year, although a recent advert (March 2006) from the Eastern Cape Development Corporation states the value of the industry as US$ 90 million per annum.

The seemingly good economic profitability of the current *A. ferox* industry has prompted interest from government and development agencies seeking opportunities for local level enterprise development for poverty alleviation in rural areas. For example, the Eastern Cape Development Corporation is working with communities and has developed a pilot-processing centre in Seymour. They have recently advertised (March 2006) in the South African Airways in-flight magazine (Indwe) for business partners and investment. The advert states that the global sales of *A. ferox* are worth US$90 million per year, with potential for up to US$2.4 billion to China alone by 2010. The Amathole District Municipality has listed *Aloe* nurseries and enterprises amongst potential job creation initiatives. A private concern has applied for construction of a processing facility in Dimbaza near Buffalo City (G. Pienaar, personal communication, Eastern Cape Department of Environmental Affairs, Economics & Tourism).

As yet there is very little ecological information on the species and thus no estimates of abundance over different climatic zones and habitats, growth rates or sustainable harvests. Newton and Vaughan (1996) report that tappers are acutely aware of the need to conserve the resource and not overharvest individual plants or populations. The recent work of Greengrass (2004) examined three harvested and three unharvested populations near Uniondale and concluded that there were no differences between harvested and unharvested populations with respect to total plant density, density of flowering plants, and density of diseased or dead plants. However, differences were found in terms of harvested populations having fewer flowers per flowering plant, and a reduced proportion of young recruits, thereby corroborating the early work of Hoffman (1988) on the pollination ecology of this species in terms of flower and seed production in relation to raceme length. Bond (1983) voiced concern that tapping may result in increased susceptibility to fire because the leaves are removed and therefore do not make a protective skirt around the stem. Sexual maturity has been estimated to occur at 4–6 years when plants are approximately 1 m tall (Newton and Vaughan, 1996); however, growth rates have never been determined empirically. Holland and Fuggle (1982) indirectly estimated the age of tall (5–6 m), mature individuals to be 150 years, which is at odds with the 4–6 years required for 1 m growth as reported above. They assumed that two whorls of leaves are produced per year, and then measured the height from the lowest whorl of mature leaves to the youngest whorl and this distance is then divided by the number of whorls / 2 to obtain a mean annual height increment.

Within the context of the above, we sought to determine the annual growth rates of *Aloe ferox* as the basis for development of population models under different harvesting and management scenarios, towards estimating sustainable harvests. Clearly this requires long term monitoring, but given the accelerating economic interest in the species, existing data need to be mobilized to prepare first estimates. This paper reports on the growth rate of 283 *Aloe ferox* plants at six unharvested sites between mid 2005 and mid 2006.

Methods

Between 40 and 50 plants were marked at each of six unharvested localities in and round Grahamstown in mid winter (late July/early August) 2005. The total number of plants was 283, ranging in height from less than 5 cm to over 2.5 m. Each plant was labelled and mapped. Plant height and the number of living, intact leaves were recorded. Because of the unusual growth form of *Aloe ferox* (and many other *Aloe* species) measurement of height was not straightforward. *Aloe ferox* has a tall narrow stem covered in woody, dead leaves with a crown of succulent leaves at the very top. The angle of the succulent leaves varies in relation to turgor pressure, and so their height is not static. In moist conditions the succulent leaves recurve out and downwards; in prolonged hot and dry conditions, the succulent leaves curl up and inwards. New leaves emerge as a rosette in the very centre of the crown, and are initially vertical, until they attain a length of several centimetres, whereafter they start to curve outwards and downwards. Therefore, on each plant we located the centremost new vertical leaf upon which we rested a 1 m long-spirit level. When the spirit-level was level we measured the height from the base of the spirit-level to the ground at a distance 50 cm along the spirit level. We also recorded the direction in which the spirit-level was pointing (as a bearing), to ensure that in subsequent years we measured the same side of the plant and so minimized differences due to sloping ground, rocks, or leaning of the plant. We also noted whether or not the plant had flowers.

In remeasuring the plants one year later a number had died. In particular, one site had been burnt and 32% of the plants were dead. Several others where obviously stressed, and seemingly dying (number of leaves vastly reduced, remaining leaves drooping and discoloured). At two other sites there was some damage from wild animals and cattle, particularly to small plants. In some instances the rosette of leaves at the top of the stem had been knocked off, and the plant was therefore shorter than 12 months previously. Several of these broken stems were now coppicing and had multiple heads. They were excluded from calculations of mean height increment. Similarly, a few particularly tall stems were also shorter than the previous year. This was a problem of the stems not being vertical, but slightly leaning. Thus, as the plant increases in size it leans more and more and so does not increase in vertical height. These stems were also excluded from the calculation of mean height increment.

Rainfall during the period (August 2005–July 2006) (as measured at Coniston farm; ± 20 km NE of Grahamstown) was 374 mm. This is 7% higher than the 18 year average of 349 mm.

Data were collated via spreadsheets and analysed using Statistica 7 (Statsoft Inc.), after testing for normality (Lilliefors test). Differences in growth rates between sites were examined via ANOVA with subsequent post-hoc comparisons via Least Significant Difference. Whether or not plants that flowered in 2006 where largely the same as those that flowered the previous year was assessed via 2 × 2 contingency tables.

Results and discussion

1. Growth

Growth varied across sites (Table 1) and plant height (Fig. 1). In terms of sites, the mean height growth ranged between 1.7 cm per plant per year at site 4 and 4.6 cm at site 2. The mean height increment across all sites and plants was 2.8 ± 0.2 cm. Plant height had a strong effect on annual increment ($r = 0.77$; $p < 0.001$) with small plants (< 6 cm) more than doubling their height in the 12 month period, whereas plants taller than 2 m grew by approximately 1% over the year. Across the five unburnt sites, the mean standing stock of leaves grew by two per plant. Based on these data, a 1 m plant is approximately 36 years old and the tallest plant in our sample (2.65 m) is approximately 95 years old. These rates are a lot lower than estimated by respondents in Newton and Vaughan's (1996) survey of *Aloe* tappers, but do need to be substantiated by longer monitoring over a series of years. Rainfall for the period was relatively close to the long term average, and thus it is probable that the measured growth rates are typical of what may be obtained via longer term monitoring.

Table 1.

Change in plant height and number of leaves of *A. ferox* between July 2005 and July 2006 at six sites in the Makana region (unlike superscripts reflect significant differences)

Site	**No. of plants (excluding plants died or coppicing, see Methods)**	**Change in height**		**Net change in no. of leaves**
		(cm)	**(%)**	
1	32	2.1 ± 0.52^{bc}	4.5 ± 1.64^{c}	-10.80 ± 1.58^{c}
2	39	4.6 ± 0.48^{a}	12.8 ± 3.33^{abc}	1.24 ± 1.15^{b}
3	37	3.2 ± 0.35^{b}	17.9 ± 4.44^{a}	1.95 ± 0.86^{ab}
4	39	1.7 ± 0.52^{c}	11.4 ± 4.79^{bc}	3.62 ± 0.50^{a}

Site	No. of plants (excluding plants died or coppicing, see Methods)	Change in height		Net change in no. of leaves
		(cm)	(%)	
5	40	3.1 ± 0.49^{b}	17.4 ± 4.78^{ab}	3.71 ± 0.65^{a}
6	49	2.3 ± 0.45^{bc}	6.1 ± 1.62^{c}	1.37 ± 0.63^{ab}
Total sample	236	2.8 ± 0.20	11.6 ± 1.51	0.51 ± 0.47 (excluding burnt site = 2.32 ± 0.36)
Significance between sites		$F_{5, 230} = 4.83$; $p < 0.001$	$F_{5, 230} = 3.15$; $p < 0.05$	$F_{5, 230} = 29.45$; $p < 0.001$

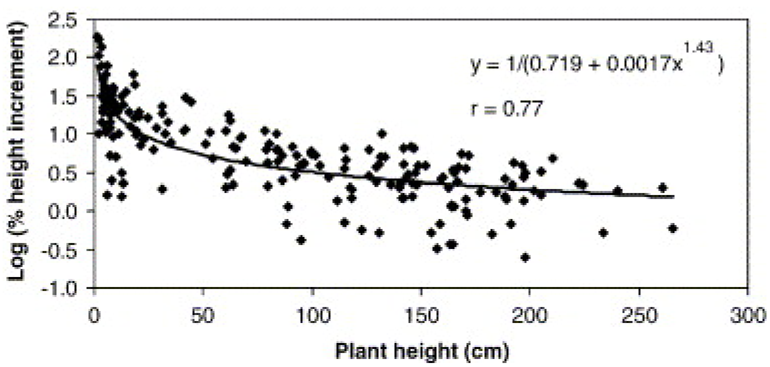

Fig. 1. Annual increment in plant height for 2005/2006 relative to plant size.

2. Flowering

The proportion of plants flowering increased progressively with plant height (Fig. 2). Although an outlier, the smallest plant with flowers was 9.3 cm tall. However, sexual maturity seems closer to 0.5 m rather than the 1 m suggested by Newton and Vaughan (1996), with at least 40% of plants in the 51–75 cm height class flowering. Most (90%) of the plants that flowered in 2005 did so again in 2006 ($\chi^2 = 170.7$; $p < 0.001$; $n = 253$).

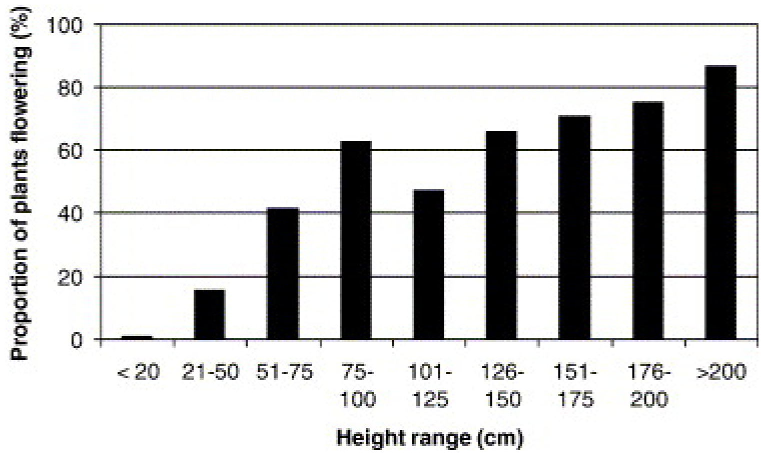

Fig. 2. The prevalence of flowering relative to plant height.

This study has provided the first basis for estimating ages and growth rates of unharvested *Aloe ferox* plants in the centre of its natural distribution. Growth rate was clearly variable between sites and was strongly related to plant size, as is common with other plant species (e.g. Shackleton, 2002 and Emanuel et al., 2005). Other aspects to consider will be the response of growth to harvesting, rainfall variability, and other potential stress or damage factors such as fire, browsing and scale insect infestation. It is not just growth that needs to be monitored in relation to these variables, but also mortality and recruitment. At site 1 there was a 32% mortality following an intense fire, and more plants are obviously under stress. This questions the success of the protective properties of the skirt of dried dead leaves around the stem as proposed by Bond (1983). At site 3 small plants were dug up or leaves stripped, probably by either porcupines and/or baboons. Baboon damage was also noted to flowers and racemes on many plants at most sites, and this was at times accompanied by broken leaves where the baboons had sat or clambered up, as also reported by Holland and Fuggle (1982). At site 2 several small plants had been smashed, but were coppicing. The damage agent at this site is presumed to be trampling by cattle. At site 6, in a nature reserve, several plants had been heavily browsed, probably by kudu or black rhinoceros. Whether or not such browsing affects growth rates or flowering success requires investigation.

Such data can then be used to help determine sustainable use levels. Growth rates of different size or stage classes and age of maturity are particularly crucial as they define the rate of throughput of individuals in the population (Bernal, 1998, Schwartz et al., 2002 and Emanuel et al., 2005). In the absence of such information managers and harvesters cannot estimate the need for or size class of individuals below which harvesting should not be permitted. Nor can they ascertain the rate of recruitment into the harvestable size classes. For *Aloe ferox* possible size classes for which harvesting should be discouraged or impossible would be the small, pre-reproductive individuals and individuals taller than 2.5 m which are too tall to be harvested by hand. Empirical determination of these across a number of populations, as done in our study, then sets the basis of modeling against which harvesting impacts and other stress factors can be evaluated, and ultimately estimates of allowable harvesting levels that a given population can sustain without long-term impacts on population structure and viability.

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