S. Afr. J. Bot. 2000, 66(2): 124–127

Stump size and the number of coppice shoots for selected savanna tree species

Charlie M. Shackleton

Centre for African Ecology, University of the Witwatersrand, P.O. Wits 2050 Republic of South Africa
Current Address: Dept of Environmental Science, Rhodes University, P.O. Box, Grahamstown 6140
Republic of South Africa

Received 3 September 1999; revised 6 March 2000

Management of coppice dynamics of indigenous savanna trees could assist in increasing the regrowth rates or number of coppice shoots produced. This would be useful in natural resource management programmes to promote sustainable resource management. This study examined the influence of cutting height, stem size and surface area on the number of coppice shoots produced for twelve savanna species from a communal land in the Bushbuckridge lowveld. All species exhibited a strong coppicing ability following cutting. The number of shoots per stump was most frequently related to cutting height, although this was not always the most significant predictor. There were clear differences between species with respect to the number of shoots per unit surface area, the highest being *for Albizia harveyii* and the least *Piliostigma thonningii*. The taller the potential height of a species, the fewer were the coppice shoots per stump surface area.

Keywords: coppice, cutting, height, regrowth, stem size.

Introduction

Cutting, lopping or other damage to trees is a common phenomenon throughout all African savannas, whether it be caused by humans or large mammals. Felling or lopping by humans is usually more severe than the effects of damage by large herbivores, but may range from selective removal of particular individuals (species and/or sizes) within a stand (Shackleton 1993), through to almost clear felling of an entire area (Chidumayo 1993). Both occur through subsistence activities such as fuelwood collection and clearing of patches for small-scale arable plots, as well as commercially orientated endeavours, such as charcoal industries and bush-clearing. Both have significant impacts on the potential productivity at the site (Chidumayo 1993; Teague & Smit 1996).

A key attribute of the resilience and productivity of savannas is the ability of damaged trees to regrow from the remaining stump. This has been well studied following fires (Bond 1997), but less so after chopping, other than after bush-thinning operations (Scholes 1990; Teague & Smit 1996). Survival of the cut stem and growth rate of the resultant coppice shoots is influenced by several factors, including size of the tree, height of cutting, and root/shoot ratio after felling (Tschaplinski & Blake 1989; Shackleton 1997). Some of these can be manipulated by the manager or harvester to maximise or suppress subsequent regrowth rates. Therefore, it is necessary to have an understanding of the external management and site factors that influence coppice regrowth for individual species. Such an understanding is well established regarding species of silvicultural importance, from both an anatomical (e.g. Burrows 1990; Paukkonen *et al.* 1992 a,b) and management (e.g. Bowersox *et al.* 1990; Johansson 1992 a,b) perspective, but not for indigenous savanna species. In South Africa, regrowth rates of savanna trees after chopping or clearing have been considered by Milton (1988), Scholes (1990) and Shackleton (1997), but only the last within the framework of seeking to optimise regrowth rates by selecting the size of tree and height of cutting. Given the wide use of savanna tree species for fuelwood and building timber (e.g. Liengme 1983; Banks *et al.* 1996), this needs to be addressed so the results can be formulated into management guidelines for natural resource management programmes and community-based initiatives seeking to encourage sustainable utilisation of woodland resources. Within this framework, the objective of this study was to determine the influence of cutting height and stem size on the resultant number of coppice shoots across a range of savanna species.

Study Area

The Bushbuckridge lowveld (31°0'–31°35'E; 24°30'–25°0'S), South Africa, is defined as the area between the Sabie River in the south and the Klaserie-Orpen road in the north, and the Drakensberg escapement in the west to the border with the Kruger National Park and Sabi-Sand Game Reserve in the east (Shackleton *et al.* 1995). It corresponds to the Mhala and Mapulaneng areas of the former Gazankulu and Lebowa homelands, respectively. The total area is 241 684 ha, of which most (64.7%) is under communal grazing lands.

Most of the area is regarded as semi-arid, except close to the Drakensberg escarpment. There is a strong gradient of decreasing rainfall from the escarpment eastwards, being approximately 1120 mm p.a. in the west and 600 mm p.a. in the east. There is a corresponding gradient in vegetation. According to the classification of Low and Rebelo (1996) the vegetation of the moister west is classified as Sour Lowveld Bushveld, which intergrades into Mixed Lowveld Bushveld near the 800 mm isohyet. Local dominance varies according to mean annual rainfall and slope position. Generally, the woody stratum is dominated by members of the Combretaceae, such as *Combretum apiculatum, C. collinum, C. hereroense, C. imberebe,* and *Terminalia sericea,* and the Mimosaceae, including *Acacia ataxacantha, A. gerrardii, A. nigrescens, A. swazica, Albizia harveyii* and *Dichrostachys cinerea.* Other dominant species include *Sclerocarya birrea, Strychnos madagascariensis, Peltophorum africanum* and *Pterocarpus angolensis.* Woody biomass is variable in relation to local disturbance around villages, ranging from less than 5 t/ha near settlements, to approximately 18–20 t/ha further away (Shackleton *et al.* 1994).

Materials and Methods

In the Bushbuckridge lowveld two villages were selected in communal lands at each of three points across the prevailing rainfall gradient: high rainfall (Miloro A and Miloro B), intermediate rainfall (Skagula and Timbavati) and low rainfall (Athol and Welverdiend). At each village two plots (20 × 20 m) were judgementally located, one in catenal toplands and one in catenal bottomlands. In each plot all cut stems were examined and the following recorded: (1) species,

Table 1 Relationship between number of coppice shoots (S) per cut stump and independent variables

Species	n	r^2	P	Relationship	Cutting height for 10 shoots
All species	348	0.37	< 0.001	S = 0.13(height) + 6.0	± 31 cm
Acacia exuvialis	20	0.16	> 0.05		
Acacia gerrardii	21	0.55	< 0.001	S = 0.11(height) + 5.8	± 38 cm
Albizia harveyii	24	0.63	< 0.001	S = 0.16(height) + 3.9	± 38 cm
Combretum apiculatum	29	0.33	< 0.01	S = 0.09(height) + 6.6	± 38 cm
Combretum collinum	25	0.70	< 0.001	S = 0.19(height) + 1.7	± 44 cm
Combretum hereroense	22	0.31	< 0.01	S = 0.16(height) + 6.2	± 24 cm
Dichrostachys cinerea	21	0.42	< 0.01	S = 0.17(height) + 5.2	± 28 cm
Euclea crispa	21	0.53	< 0.001	S = 0.00064(surface area) + 6.2	
Euclea natalense	24	0.73	< 0.001	S = 0.24(height) - 0.02	± 42 cm
Peltophorum africanum	25	0.67	< 0.001	S = 0.23(height) + 3.3	± 29 cm
Piliostigma thonningii	20	0.23	< 0.05	S = 0.11(height) + 5.0	± 46 cm
Terminalia sericea	22	0.35	< 0.01	S = 0.23(height) + 8.3	± 7 cm

all cut stems were examined and the following recorded: (1) species, (2) cutting height, (3) basal circumference at 5 cm above the ground (if it had been cut at a height lower than this, then the basal circumference was measured below 5 cm), and (4) the number of coppice shoots, irrespective of size or length.

The nature of the survey did not account for changing numbers of coppice shoots per stump with time since cutting or of cutting season. In the first few months after cutting shoot number increases up to a maximum; thereafter it declines as inter-shoot competition and apical dominance increase (Khan & Tripathi 1986; Lubbe 1990; Chidumayo 1993; Shackleton 1997). Studies from other species and biomes have indicated an effect of season of cutting (Johansson 1992b; Chidumayo *et al.* 1996). Stumps in this study were of different ages and had been cut in different seasons. However, the wide range of sites, localities and tree size should ensure that variance due to time since cutting would be small in comparison to all the other sources. Moreover, the analysis was across species, all of which had a number of stumps of different ages since cutting. This was the reason for using number of coppice shoots as an index of regrowth rather than mass of coppice growth.

Data were pooled by species across the plots. Species for which twenty or more stumps were recorded were subjected to stepwise linear regression with the number of coppice shoots as the dependent variable and the height of cutting, basal circumference, and stump surface area as independent variables. A Mann-Whitney test was used to test the significance of differences between species groups. The relationship between mean stump surface area per coppice shoot and potential height of the tree was examined via linear regression. Potential tree height was obtained from a random selection of one third of all the vegetation plots collected from protected areas in the immediate vicinity by Shackleton (1997). These data were pooled, and sorted according to species and height per stem. The mean of the ten tallest stems per species was taken as the potential maximum tree height for that region. Analysis of residuals of the initial insignificant regression indicated the presence of potential outliers. Subsequent analysis of the significance of potential outliers indicated that *Piliostigma thonningii* and *Albizia harveyii* were significant ($p < 0.01$ and $p < 0.05$, respectively). These two species were then omitted from the final regression analysis relating coppice density per stump and mean potential height of a species.

Results

All species exhibited a strong coppicing potential following cutting. No stumps were found that did not have at least one coppice regrowth shoot. The number of shoots per stump were most frequently related to cutting height (Table 1), although this was not always the most significant predictor. Two species showed no relationship with cutting height, namely *Euclea crispa* and *Acacia exuvialis*. For *Euclea crispa* a significant relationship was evident with stump surface area. For *Acacia exuvialis* no significant relationships were established (Table 1). It was hypothesised that the strong relationship with cutting height is manifest through the influence of cutting height on the surface area of the stump. However, surface area was not a frequent predictor variable. The high slopes of the relationship for *E. natalense*, *T. sericea*, and *P. africanum* indicate that a change in cutting height will have the most effect on these species in terms of increasing the resulting number of coppice shoots. Species with the least slope (*C. apiculatum*, *A. gerrardii*, *P. thonningii*), are the least sensitive to changes in cutting height as a means of influencing the resultant number of coppice shoots.

There were clear differences between species with respect to the number of shoots per unit surface area, or the inverse, unit area per shoot (Table 2). The species with most coppice shoots per stump area (*Albizia harveyii*) had almost ten times more than the species with the least, *Piliostigma thonningii*. There was a significant difference ($U_{7,5} = 30$; $p < 0.05$) in mean unit area per shoot of those species for which cutting height was the most significant predictor variable of coppice stem number ($\bar{x} = 683.6 \pm 117$; $n = 7$) and those for which height was not ($\bar{x} = 365.0 \pm 73.9$; $n = 5$), even though it may have been significant.

There was a strong relationship between the mean surface area of stump per shoot (shoot density) and potential height of each species (omitting outliers; see methods), summarised in the form:

$$y = 234.4*(\ln(\text{potential height}) + 157.7 \quad (r^2 = 0.48;\ p < 0.03;\ n = 10)$$

Thus, the taller the potential height of a species, the fewer the coppice shoots per stump surface area.

Table 2 Mean unit area per coppice shoot per species (ordered from highest to lowest) (unlike letters indicate a significant difference at the 95% level or greater)

Species	Unit area (cm^2)	SE	n	Sig. diff.	Mean potential height (m)
Piliostigma thonningii	1258.7	285.3	20	a	4.63
Acacia gerrardii	850.9	150.7	21	b	7.90
Combretum collinum	761.6	86.5	25	bc	10.40
Peltophorum africanum	622.4	53.9	25	bcd	5.69
Dichrostachys cinerea	588.4	54.1	21	bcde	3.56
Combretum hereroense	491.0	75.6	22	cde	4.19
Combretum apiculatum	468.1	74.5	29	de	3.96
Euclea crispa	401.1	56.0	21	def	2.96
Terminalia sericea	389.0	93.0	22	def	10.72
Euclea natalense	332.2	43.0	24	ef	1.98
Acacia exuvialis	316.6	42.9	20	ef	3.60
Albizia harveyii	130.0	14.3	24	g	8.09

Discussion

The results indicate that through a combination of easily applied management considerations and actions the resultant number of coppice shoots can be manipulated. The first consideration is which tree to cut based on its size. It seems that increasing stem size results in either (1) an increasing number of coppice shoots, or (2) has no effect. Where an effect is evident it is probably a result of the greater surface area per stump, and greater root/shoot ratio. A positive relationship was evident for eight of the twelve species examined. Bowersox *et al.* (1990) found no relationship between these two parameters, but Whitesell *et al.* (1985) (in Bowersox *et al.* 1990) also recorded a positive relationship, as did Shackleton (1997) for *Terminalia sericea*. Some authors have found a negative relationship. For example, McDonald and Powell (1983) found a decreasing survivorship of stumps and number of shoots per stump with increasing stump size for *Acer saccharum*. Khan and Tripathi (1986) found decreasing coppicing ability with increasing stem size for four sub-tropical forest species, as did Chidumayo (1993). This has been ascribed to the increased bark thickness of larger stems hindering emergence of the bud (Khan & Tripathi 1986). In savannas, thick bark is regarded as an adaptation to a fire prone environment. None of the species covered in this study have particularly thick bark (for savanna species) and only one species, *D. cinerea*, displayed a negative relationship between shoot number and stem size. Clearly, the consideration of what size tree to fell is the result of several factors, including what the timber will be used for, ease of transportation and what is available. Potential regrowth dynamics is another factor to consider within a natural resource management framework.

Having selected the size of tree the manager or harvester has options regarding the height at which to cut the tree, in order to suppress or encourage the number of subsequent regrowth shoots. Increased cutting height appears to have a positive effect on the number of coppice shoots. This is supported by data from other species and vegetation types (e.g. Harrington 1984; Khan & Tripathi 1986; Bowersox *et al.* 1990; Huang 1990; Shackleton 1997). This may be related to increased stump surface area with increasing cutting height (Canadell *et al.* 1991), but many studies did not investigate the influence of area, just height. Survival of the cut tree is also positively related to cutting height (Bowersox *et al.* 1990; Johansson 1992a). The positive effects of increased cutting height must be balanced against the loss of useful timber that is left behind as stump. However, changing the cutting height is an easy management action to implement, with marked effects on the resultant coppice number and hence, harvest turnover time.

The relationship between mean potential height and the number of coppice shoots per stump provides a differentiating variable regarding plant growth form. In shorter, shrubby species new growth goes into multiple shoots, whereas for taller, tree species, new growth is concentrated into fewer shoots. The lower density of shoots will result in faster growth rates due to reduced intershoot competition. Thus, it appears that tall species allocate resources in a manner advantageous to them regaining a height advantage after felling. Shorter species allocate resources into more shoots that would grow at a slower rate. This multiple coppice shoot strategy for shorter, shrubby species appears to suggest another growth allocation pattern in addition to the two already recognised by Hara *et al.* (1991), those being height growth species and crown growth species. The relationship with maximum potential tree height tends to reinforce the positive relationship found with stem diameter and coppice shoot number, since height and diameter are well correlated for most tree species.

In conclusion, the number of coppice shoots produced by savanna trees and shrubs is influenced by species and stump dimensions, particularly cutting height. The management application of this depends upon the management objectives of the area under consideration. For example, if managers wish to optimise browse production in the harvested area, a greater cutting height is recommended, as this will result in larger number of coppice shoots available as browse. If however, the objective is to minimise the rotation time between harvests a lower cutting height is advocated as this will result in fewer shoots, contributing to an earlier establishment of apical dominance. Of the species considered *E. natalense*, *T. sericea* and *P. africanum* are the most sensitive to changes in cutting height with respect to resulting number of coppice shoots.

Acknowledgements

Thanks are due to the Green Trust, and Wits Rural Facility for sponsorship of this work and to Bob Scholes who commented on earlier drafts of this write-up.

References

BANKS, D.I., GRIFFIN, N.J., SHACKLETON, C.M., SHACKLETON, S.E. & MAVRANDONIS, J.M. 1996. Wood supply and demand around two rural settlements in a semi-arid savanna, South Africa. *Biom. Bioen.* 11: 319–331.

BOND, W.J. 1997. Fire. In: Vegetation of Southern Africa, eds. R.M. Cowling, D. M. Richardson & S.M Pierce. Cambridge: Cambridge University Press. pp. 421–446.

BOWERSOX, T.W., SCHUBERT, T.H., STRAND, R.F. & WHITESELL, C.D. 1990. Coppicing success of young *Eucalyptus saligna* in Hawaii. *Biomass* 23: 137–148.

BURROWS, G.E. 1990. The role of axillary meristems in coppice and epicormic bud initiation in *Araucaria cunninghamii. Bot. Gaz.* 151: 293–301.

CANADELL, J., LLORET, F. & LOPEZ-SORIA, L. 1991. Resprouting vigour of two mediterranean shrub species after experimental fire treatments. *Vegetatio* 95: 119–126.

CHIDUMAYO, E.N. 1993. Responses of miombo to harvesting: ecology and management. SEI, Stockholm. 110 pp.

CHIDUMAYO, E.N., GAMBIZA, J. & GRUNDY, I. 1996. Managing miombo woodlands. In: Miombo in transition: woodlands and welfare in Africa, ed. B. Campbell. CIFOR, Bogor. pp. 175–193.

HARA, T., KIMURA, M. & KIKUZAWA, K. 1991. Growth patterns of tree height and stem diameter in populations of *Abies beitchii, A. mariesii* and *Betula ermanii. J. Ecol.* 79: 1085–1098.

HARRINGTON, C.A. 1984. Factors influencing initial sprouting of red alder. *Can. J. For. Res.* 14: 357–361.

HUANG, S. 1990. Study on the effect of stump diameter and height on sprout regeneration in mangium *(Acacia mangium* Willd.). *For. Res.* 3: 242–249.

JOHANSSON, T. 1992a. Sprouting of 2- to 5-year-old birches *(Betula pubescens* Ehrh. and *Betula pendula* Roth) in relation to stump height and felling time. *For. Ecol. Mgmt.* 53: 263–281.

JOHANSSON, T. 1992b. Sprouting of 10- to 50-year-old *Betula pubescens* in relation to felling time. *For. Ecol. Mgmt.* 53: 283–296.

KHAN, M.L. & TRIPATHI, R.S. 1986. Tree regeneration in a disturbed sub-tropical wet hill forest of north-east India: effect of stump diameter and height on sprouting of four tree species. *For. Ecol. Mgmt.* 17: 199–209.

LIENGME, C.A. 1983. A study of wood use for fuel and building in an area of Gazankulu. *Bothalia* 14: 245–257.

LOW, A.B. & REBELO, A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. DEAT, Pretoria.

LUBBE, W.A. 1990. Management of the coppice regeneration of *Ocotea bullata* (Lauraceae). *S. Afr. For. J.* 54: 1–6.

MCDONALD, J.E. & POWELL, G.R. 1983. Relationships between stump sprouting and parent-tree diameter in sugar maple in the first year following clear-cutting. *Can. J. For. Res.* 13: 390–394.

MILTON, S.J. 1988. The effects of pruning on shoot production and basal increment of *Acacia tortilis. S. Afr. J. Bot.* 54: 109–117.

PAUKKENEN, K., KAUPPI, A. & FERM, A. 1992a. Origin, structure and shoot-formation ability of buds in cutting-origin stools of *Salix* 'aquatica'. *Flora* 186: 53–65.

PAUKKENEN, K., KAUPPI, A. & FERM, A. 1992b. Root and stump buds as structural faculties for re-invigoration in *Alnus incana* (L.) Moench. *Flora* 187: 353–367.

SCHOLES, R.J. 1990. The regrowth of *Colophospermum mopane* following clearing. *J. Grassl. Soc. Sth. Afr.* 7: 147–151.

SHACKLETON, C.M. 1993. Fuelwood harvesting and sustainable utilisation in a communal grazing land and protected area of the eastern Transvaal lowveld. *Biol. Cons.* 63: 247–254.

SHACKLETON, C.M. 1997. The prediction of woody productivity in the savanna biome, South Africa. PhD thesis, University of the Witwatersrand, Johannesburg. 204 pp.

SHACKLETON, C.M., GRIFFIN, N.J., BANKS, D.I., MAVRANDONIS, J.M. & SHACKLETON, S.E. 1994. Community structure and species composition along a disturbance gradient in a communally managed South African savanna. *Vegetatio* 115: 157–167.

SHACKLETON, S.E., STADLER, J.J, JEENES, K.A., POLLARD, S.P. & GEAR, J.S. 1995. Adaptive strategies of the poor in arid and semiarid lands: in search of sustainable livelihoods - a case study of the Bushbuckridge district, Eastern Transvaal, South Africa. Unpubl. rep., Wits Rural Facility, Klaserie.

TEAGUE, W.R. & SMIT, G.N. 1992. Relations between woody and herbaceous components and the effects of bush-clearing in southern African savannas. *J. Grass. Soc. Sth. Afr.* 9: 60–71.

TSCHAPLINSKI, T.J. & BLAKE, T.J. 1989. Photosynthetic re-invigoration of leaves following shoot decapitation and accelerated growth of coppice shoots. *Physiol. Plant* 75: 157–165.