THE EFFECT OF SEASON AND TREATMENT ON THE SURVIVAL RATE AND COPPICING ABILITY OF FIVE ENCROACHING WOODY SPECIES.

II: The effect of fire-girdling.

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ABSTRACT

Five encroaching species (*Acacia mellifera, A. nilotica, Dichrostachys cinerea, Terminalia prunioides* and *T. sericea*) have been fire-girdled at various heights and during various seasons. The height of coppice has been measured at two assessments after fire-girdling and the number of dead plants noted. The regrowth was the lowest and mortality rate the highest for trees fire-girdled during the rainy season, i.e. between January and April. Fire-girdling is also most effective if done as near to groundlevel as possible. A minimum duration and intensity of the fire must be achieved, for fire-girdling to be effective. Post fire-girdling treatments, especially with browsers, is suggested, as coppicing does occur.

INTRODUCTION

Bush encroachment is a serious problem in especially the northern parts of Namibia (Bester, undated, see also Strohbach, 1996). Next to clear-felling and the use of herbicides, fire is often used to control woody plants. Veld fires are not regarded as an effective means in reducing the number of woody plants, as

(i) larger trees and shrubs do not die from fire, and often regrow strongly;

(ii) A suitably high fuel-load is not always available, and

(iii) Grazing management is often in conflict with the use of fires. (Trollope, 1974)

An alternative to the use of veld fires is fire-girdling ("stambrand"). In this process a fire is made at the base of the tree, either using wood, cattle dung or rubber from tubes as fuel. Donaldson (1967) described an apparatus to fire-girdle stems with butane (LPG) as fuel. He had considerable success with this apparatus, provided he burned the stems for at least 3 minutes or longer for a shrub/tree to be killed.

Donaldson's problem with the minimum burn-time of 3 minutes can be explained by the anatomy of the stem, and the function of the various tissues in the stem.

Growth in the stem occurs in two tissue systems: The apical meristem is situated in the points of twigs. In these meristems active cell division takes place. Just below this apical meristem, the newly formed cells differentiate into various tissues - vascular bundles consisting of xylem, phloem and fascicular cambium, in a matrix of parenchyma cells, and surrounded by a layer of sclerenchyma cells forming the bark. Further down, these cells elongate, in this way causing the stem to grow in length (Fahn, 1982).

Thickening of the stem results from cell divisions within the cambium. The original vascular bundle consists of three segments: an inner bundle of xylem cells (these are primarily responsible for water transport from the roots to the leaves), an outer bundle of phloem cells (these are primarily responsible for the active transport of nutrients from the leaves to other organs like roots), and in between a thin layer of cambium (Figure 1) (Fahn, 1982). The cambium cells (or lateral meristem) actively divides inwards and outwards. The result is a fixed ring of phloem, the cambium strips linking up, and an inner core of xylem (or wood). The older phloem cells to the outside die off to form the bark.

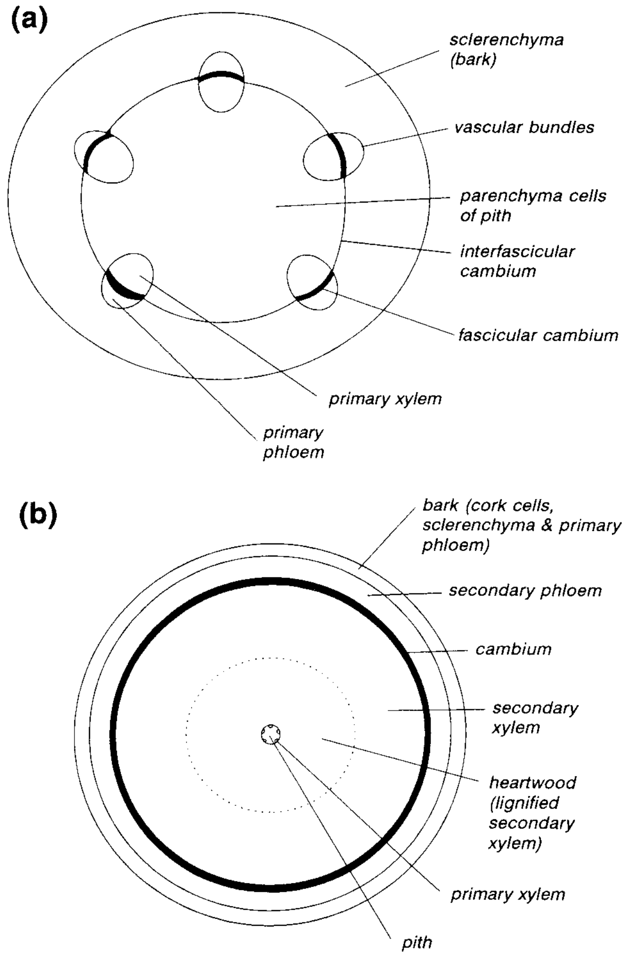

Figure 1: Line diagram of the anatomy of (a) a young stem, and (b) an older stem, after Fahn, 1982.

Similar to fire-girdling, girdling or ring-barking is also used to kill trees. In the process a ring of "bark" is removed around the stem. Noel (1968) and Teague & Killilea (1990) pointed out that for effective girdling, care must be taken not only to remove the bark, but also the phloem and especially the cambium must be removed. If the cambium is not properly removed, bridging can occur, and growth above the girdling mark continues. Thus fire-girdling can only be effective if enough heat is generated to destroy the bark as well as the underlying phloem and cambium.

STUDY SITES AND METHODS

Study sites and experimental methods

The same species used for the trials on the effect of felling, i.e. *Acacia mellifera, Acacia nilotica, Terminalia sericea, T. prunioides* and *Dichrostachys cinerea*, have been used to determine the effects of fire-girdling (Strohbach, 1996). The study sites are fully described in the above paper.

The apparatus described by Donaldson (1967) was reconstructed and used for fire-girdling the test plants (Strohbach, 1991). In the respective stands of each species, 10 plants were fire-girdled at 5 cm above the ground, a further 10 plants at 20 cm above the ground and another 10 plants at 50 cm above the ground. This treatment was repeated every second month, coinciding with the felling treatments described by Strohbach (1996). Fire-girdling was applied for approximately 3 minutes per stem, thus following the recommendations of Donaldson (1967). Treatments were discontinued after one year. In this way 900 plants were treated.

The plants were permanently marked with metal markers. The height before fire-girdling, the stem diameter at fire-girdling height, and especially with *Acacia mellifera*, the number of stems, and the general phenology of the plant (i.e. in flower or not, etc.) were noted down at the time of treatment.

Data processing

Since treatment during 1990/1991, two assessments of the fire-girdled plants (in May 1992, and again in April 1993) have been done. During assessment, the height of the living parts of the plants was measured. In a case where no regrowth is visible after a year, the plant was presumed to be dead.

Cambial bridging occurred in several instances, necessitating the exclusion of these trees from the results. The number of trees where cambial bridging occurred, has been indicated in the results (Tables 1 - 5).

In the reduced sample, the average height of regrowth for each treatment (i.e. height of fire-girdling x fire-girdling date) was calculated for each observation separately, as well as the % mortality for each treatment. These results are also given in Tables 1 - 5.

The regrowth of the plants and the % mortality were plotted against the season of treatment. The season of treatment was plotted as starting from July and ending in June. This was done to be able to compare the graphs with the climate diagrams for the test sites, as they appear in Strohbach (1996).

RESULTS

Acacia mellifera (Vahl) Benth.

With *Acacia mellifera,* cambial bridging was only observed on two trees fire-girdled during June 1991 (Table 1).

Table 1: Reaction of *Acacia mellifera* to fire-girdling at various heights and seasons.

Date of fire-girdling	Height of fire-girdling (cm)	% mortality		Average height (cm)		No of trees showing cambial
		year 1	year 2	year 1	year 2	
1.8.1990	5	60	80	24	4	0
	20	60	60	30	24	0
	50	0	0	60	50	0
8.10.1990	5	80	80	4	4	0
	20	0	80	44	4	0
	50	0	25	80	50	0
3.12.1990	5	80	100	10	0	0
	20	0	0	60	50	0
	50	0	0	60	60	0
31.1.1991	5	40	40	14	12	0
	20	20	20	22	22	0
	50	60	80	14	4	0
28.3.1991	5	30	40	14	15	0
	20	20	60	28	8	0
	50	40	60	24	30	0
3.6.1991	5	60	100	14	0	0
	20	0	50	35	25	2
	50	0	40	24	30	0

Mortality percentages of up to 100 % were obtained by fire-girdling the trees 5 cm above the ground (Figure 2). The treatments done during the rainy season (i.e. at the end of January and end of March) were not as effective as those done during the dry season. Here only a 40 % mortality was obtained.

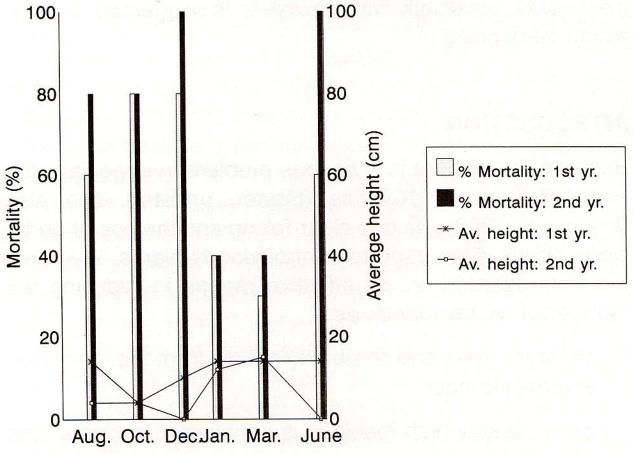

Figure 2: Regrowth and mortality of *Acacia mellifera,* after being fire-girdled 5 cm above ground level.

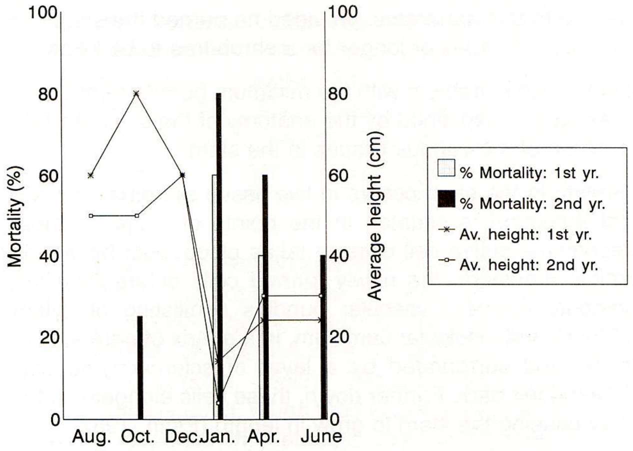

Figure 3: Regrowth and mortality of *Acacia mellifera,* after being fire-girdled at 50 cm above ground level.

The opposite is true for trees fire-girdled 50 cm above the ground. Here mortality of up to 80 % was obtained after treatment at the end of January, while the treatments done out of the rainy season show a maximum mortality of 40 % for the June treatments, and 25 % for the October treatments (Figure 3).

Trees fire-girdled at 20 cm above ground level showed a mixed tendency - mortalities occurred with all treatment dates except beginning of December. Trees treated during October died only during the second year of treatment, but here mortality is as high as 80 % (Figure 4). The sudden dieback after a successful season of coppicing can only be explained by the occurrence of a secondary stress factor, i.e. because of a possible drier location, or due to fungal infection (Holz & Schreuder, 1989).

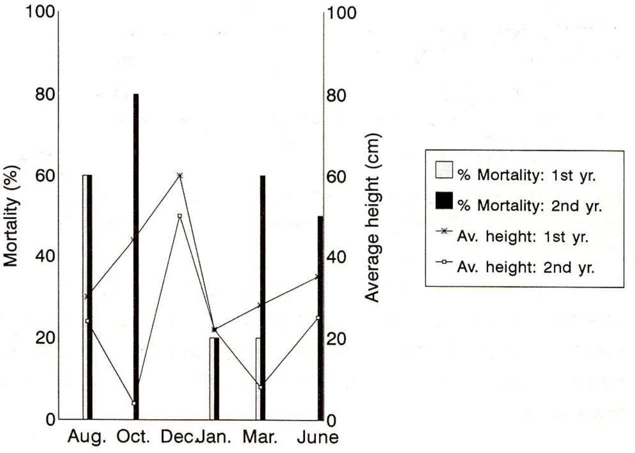

Figure 4: Regrowth and mortality of *Acacia mellifera,* after being fire-girdled 20 cm above the ground.

These results indicate that fire-girdling of *Acacia mellifera* trees at ground level is very effective. Even the treatments done during the rainy season show coppicing only up to an average height of 15 cm (Table 1). This corresponds well with the findings of Donaldson (1967), who found effective rootkill to occur after fire-girdling trees at ground level for 3 minutes or more.

Acacia nilotica (L.) Willd. ex Del.

Cambial bridging was noted on 8 trees during October 1990 (Table 2). This was presumed to be the result of inaccurate application of the methods during the fire-girdling operation. Thus the October treatment has been repeated during 1991. However, the results obtained during October 1991 are very different from those obtained during October 1990. The reason is not clear, but could be the result of a number of factors, like the rainfall during the season before and/or after the year of treatment, or other weather factors such as the intensity and duration of the hot, dry spring and summer months before the rain starts.

Table 2: Reaction of *Acacia nilotica* to fire-girding at various heights and seasons.

Date of fire-girdling	Height of fire-girdling (cm)	% mortality		Average height (cm)		No of trees showing cambial
		year 1	year 2	year 1	year 2	
30.7.1990	5	60	77	30	17	0
	20	20	55	50	55	0
	50	0	0	135	125	0
9.10.1990	5	0	0	66	113	1
	20	16	16	58	83	4
	50	0	0	121	143	3
5.12.1990	5	40	70	30	20	0
	20	0	0	80	80	0
	50	0	0	100	140	0
1.2.1991	5	60	90	20	5	0
	20	10	30	35	20	0
	50	10	90	20	10	0
27.3.1991	5	50	100	15	0	0
	20	20	60	35	30	0
	50	20	80	30	20	0
4.6.1991	5	20	50	40	27	0
	20	0	30	50	45	0
	50	0	33	61	50	1
7.10.1991	5	20	10	40	0	0
	20	0	0	40	44	1
	50	0	0	50	95	0

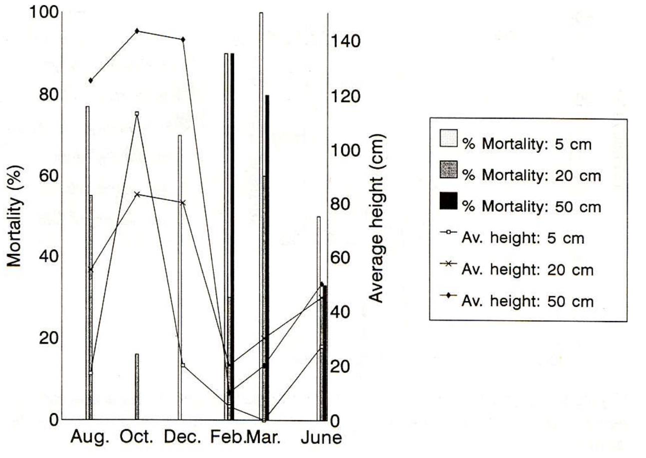

Figure 5: Regrowth and mortality of *Acacia nilotica* as assessed two years after treatment, after being fire-girdled at various heights above the ground.

Comparing the results of various fire-girdling heights and seasons (excluding the October 1991 treatment), it is clear that (i) fire-girdling at 5 cm above the ground results in the highest percentage mortality, and the least coppicing, and (ii) treatments during the rainy season also result in low amounts of coppice and high mortalities (Figure 5).

It seems that the treatments done during the rainy season at 20 cm above ground level are less effective than treatments done at either 5 cm or 50 cm above ground level. The reason for this is not clear.

Dichrostachys cinerea (L.) Wight & Arn.

As observed with the felling operation (Strohbach, 1996), mortality is extremely low with *Dichrostachys cinerea* after treatment. Only a total of 3 shrubs were killed by the treatment. Again, a total of 4 trees showed cambial bridging (Table 3).

Table 3: Reaction of *Dichrostachys cinerea* to fire-girdling at various heights and seasons.

Date of fire-girdling	Height of fire-girdling (cm)	% mortality		Average height (cm)		No of trees showing cambial
		year 1	year 2	year 1	year 2	
30.7.1990	5	0	0	130	140	0
	20	0	0	111	138	0
	50	0	0	180	165	0
9.10.1990	5	0	0	106	128	1
	20	0	0	130	139	0
	50	0	0	180	150	0
4.12.1990	5	0	0	100	95	0
	20	0	0	140	120	0
	50	0	0	150	135	0
4.2.1991	5	10	10	24	24	0
	20	0	0	47	54	0
	50	0	0	80	115	0
27.3.1991	5	10	10	42	44	0
	20	0	0	85	59	0
	50	0	10	75	63	1
4.6.1991	5	0	0	69	58	2
	20	0	0	110	100	0
	50	0	0	185	120	0

Comparing the effectiveness of fire-girdling at various heights, Figure 6 shows that fire-girdling should be applied as near as possible to the ground and also during the rainy season. Two of the three trees which were killed, were treated during the rainy season at 5 cm above the ground level. The third tree which died was also treated during the rainy

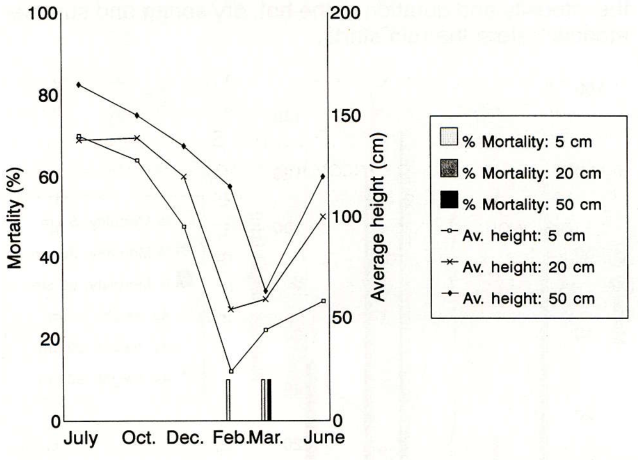

Figure 6: Regrowth and mortality of *Dichrostachys cinerea* as assessed two years after treatment, after being fire-girdled at various heights above the ground.

season, but was fire-girdled at 50 cm above ground level. The reason for this kill can be attributed to the fact that the shrub was an old plant (at treatment it was 3 m high with a stem diameter of 36 mm), indicating that the age of the plants also has an effect on the mortality rate.

Table 4: Reaction of *Terminalia prunioides* to fire-girdling at various heights and seasons.

Date of fire-girdling	Height of fire-girdling (cm)	% mortality		Average height (cm)		No of trees showing cambial
		year 1	year 2	year 1	year 2	
30.7.1990	5	50	50	25	25	0
	20	0	0	40	44	2
	50	12	33	86	64	3
9.10.1990	5	30	30	40	37	0
	20	0	18	50	60	0
	50	0	0	105	120	0
4.12.1990	5	30	30	29	35	0
	20	0	0	83	83	1
	50	0	0	60	60	0
4.2.1991	5	11	44	49	13	1
	20	0	0	60	62	0
	50	0	0	100	100	0
27.3.1991	5	0	20	47	37	0
	20	0	0	50	50	0
	50	0	0	70	75	0
3.6.1991	5	20	20	26	25	0
	20	0	0	105	80	0
	50	0	0	90	75	0
29.7.1991	5	70	80	15	7	0
	20	0	0	47	38	0
	50	0	0	65	70	0

Terminalia prunioides Lawson

The samples of *Terminalia prunioides* which were treated were often bigger than those treated for other species (up to 4 m high). The bark was generally thicker, resulting in a number of trees showing cambial bridging (Table 4).

Again, fire-girdling at 5 cm above ground level showed the highest mortality rate and the least coppicing (Figure 7). Coppicing was also reduced with the higher fire-girdling

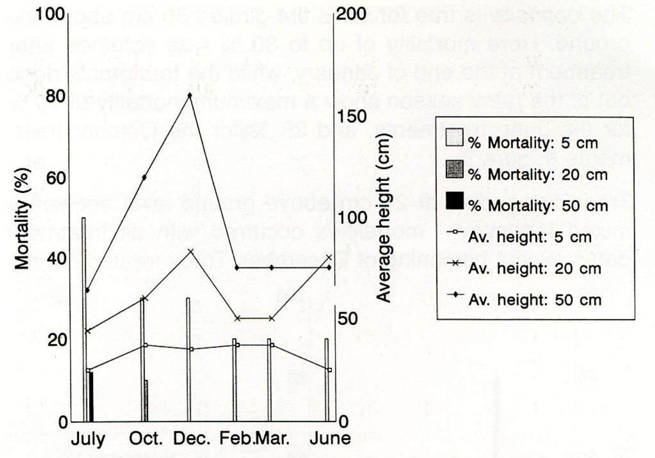

Figure 7: Regrowth and mortality of *Terminalia prunioides* as assessed two years after treatment, after being fire-girdled at various heights above the ground

treatments done during the rainy season. Again, the age/size of the trees also seems to be important: the only trees which died after being fire-girdled at 20 cm or 50 cm, were higher than 3 m, and had a stem diameter of more than 60 mm.

Table 5: Reaction of *Terminalia sericea* to fire-girdling at various heights and seasons.

Date of fire-girdling	Height of fire-girdling (cm)	% mortality		Average height (cm)		No of trees showing cambial
		year 1	year 2	year 1	year 2	
26.3.1991	5	0	0	110	95	0
	20	0	11	106	127	1
	50	0	0	150	140	0
5.6.1991	5	0	0	180	165	0
	20	0	0	166	177	1
	50	0	0	190	230	0
31.7.1991	5	0	0	135	90	0
	20	0	0	170	125	0
	50	0	0	200	175	0
8.10.1991	5	10	11	110	115	1
	20	0	0	140	155	0
	50	0	0	155	140	0
26.11.1991	5	0	0	100	60	0
	20	0	0	100	65	0
	50	0	0	100	100	0
4.2.1992	5	0	0	100	60	0
	20	0	0	100	55	0
	50	0	0	100	50	0

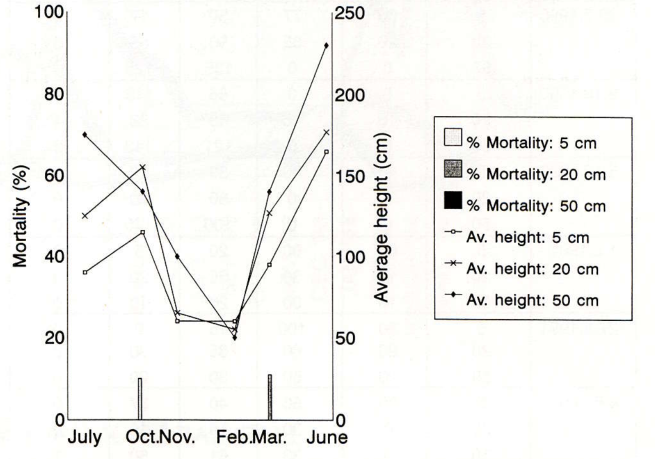

Figure 8: Regrowth and mortality of *Terminalia sericea* as assessed two years after treatment, after being fire-girdled at various heights above the ground.

Terminalia sericea Burchell ex DC.

Terminalia sericea also shows an ability to bridge damage to the cambium - three trees did show such cambial bridging (Table 5).

Similar to the results obtained from felling treatments, very little difference was observed between the effects of the various heights of fire-girdling (Figure 8). The two plants which were killed, were fire-girdled 5 cm (treated during October 1991) and 20 cm (treated during March 1992) above ground levels. From this evidence it can again be deduced that the lower treatment heights are more effective in killing the trees.

Again, a drop in the amount of coppicing was observed in all trees treated during the rainy season. Other than what was observed with the other species, the coppicing rate was reduced with shrubs treated at the end of November already, and the effect on the amount of coppice was reduced dramatically by the middle of the rainy season (as from March).

This earlier sensitivity to treatment can be attributed to the phenology of the trees. Flushing starts as early as October, as opposed to the beginning of the rainy season with the other species. This flushing depletes nutrient levels in the roots, making the trees sensitive for felling or fire-girdling treatments. The nutrients seem to be replenished as early as March in a process probably similar to translocation as described for grasses by Tainton (1981).

DISCUSSION

In general it was shown that fire-girdling, as with felling, is most effective if done as near to ground level as possible. Also concurrent with results obtained for felling, the most effective time to treat the trees is during the active growing period. Evidence obtained from the trial with *Terminalia sericea* suggests that the active growth period, rather than the rainy season, is the period during which trees are most susceptible to damage by fire and/or felling.

As cambial bridging was observed on several occasions, the necessity of a minimum time span of fire-girdling, to effectively destroy the cambium, was again demonstrated. Donaldson (1967) already described this phenomenon, thus explaining the ineffectiveness of a veldfire to destroy encroaching woody species. In most cases the available fuel at the stem base is insufficient to support a prolonged hot fire, as very little grass is available underneath a tree/shrub canopy to add to the fuel load.

As a 100% mortality rate is not achieved, and coppicing does occur, post fire-girdling treatments are essential. The removal of coppice was shown by Teague & Killilea (1990) to be effective in killing trees after girdling. A similar approach is suggested, especially by means of browsers. Trollope (1974) found that stocking lightly with goats was effective to control the coppice of bush after a veld fire, with no detrimental effect to the grass.

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REFERENCES

BESTER, F.V. Undated. Die verbossingsprobleem in Suidwes-Afrika. Unpublished report, Administration for Whites.

DONALDSON, C.H., 1967. Further findings on the effects of fire on blackthorn. *Proc. Grassld. Soc. Sth. Afr.* 2:59-61.

FAHN, A., 1982. Plant Anatomy. Third Edition. Oxford: Pergamon Press. 543 pp.

HOLZ, G. & SCHREUDER, W., 1989. Dieback of blackthorn (*Acacia mellifera* subsp. detinens) in South West Africa. *Agricola* 7:32-36.

NOEL, A.R.A., 1968. The effects of girdling, with special reference to trees in south central Africa. *Kirkia* 6:181-196.

STROHBACH, B.J., 1991. Die Donaldson bosbrander. *Agri-Info* 4(1&2): 12-13.

STROHBACH, B.J., 1996. The effect of season and treatment on the survival rate and coppicing ability of five encroaching woody species. I: The effect of felling heights. *Agricola* (in press.)

TAINTON, N.M., 1981. The grass plant and its reaction to treatment. In: Veld and Pasture Management in South Africa (ed.: N.M. Tainton), Chapter 8. Pietermaritzburg: Shuter & Shooter.

TEAGUE, W.R. & KILLILEA, DIANE M.,1990. The effect of ring-barking *Brachystegia spiciformis* Benth., *Julbernardia globiflora* (Benth.) Troupin and *Terminalia sericea* Burch. ex Dc. trees at different heights with or without the addition of a picloram/2,4-D mixture. J. *Grassl. Soc. South. Afr.*, 7(3):157-165.

TROLLOPE, W.S.W., 1974. Role of fire in preventing bush encroachment in the eastern Cape. *Proc. Grassld. Soc. Sth. Afr.* 9:67-72.

VERSVELD, W.V.R., 1985. Veldbrand as 'n hulpmiddel in die beheer van bosindringing. *Agricola* 2:22-24.