Vegetational response to herbicide treatment for brush control in Tanzania

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Abstract

Dense stands of small trees restrict understory production and provide suitable habitat for tsetse-fly in many areas in Tanzania. Three methods (ring barking, cut stump and frilling) of applying a mixture of esters of 2,4-D (2,4-dichlorophenoxy acetic acid) and 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) for tree control were compared. There were no significant differences in mortality ($P<0.10$) of *Combretum* species among the application methods. Mortalities for all species ranged from 37 to 48%. Applications in June had pronounced effects on *Combretum molle* and *Combretum ternifolium* on the reddish-brown soil and black soils sites, respectively. *Combretum binderanum* on the reddish-brown soil site tended to respond differently in June and December to cut stump and ring barking treatments. Overall, *Combretum molle* and *Combretum ternifolium* were more susceptible to the herbicide treatments than was *Combretum binderanum*. Total herbage standing crop in the reddish-brown soil site was not affected by method or the season of herbicide application ($P>0.10$). On the black soil site *Andropogon gayanus* and forbs produced more herbage standing crop under the ring barking treatment in June compared to the control. Percent composition of *Panicum infestum* on the reddish-brown soil site was higher in the June herbicide applications than that in December applications. On the black soil site, composition of *Andropogon gayanus* was significantly lower in the December ring barking treatment than in the control, whereas forb composition was significantly higher ($P<0.10$) in the June ring barking treatment compared to the control. The frilling treatment applied in June appeared to give the most positive response for management objectives.

Key Words: *Combretum*, brush management, understory response

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Much of eastern Africa is covered by woodland vegetation with shrubs and small trees (less than 20 m tall) of varying densities (Pratt and Gwynne 1977). In some cases this woody vegetation suppresses growth of understory grasses and other herbaceous vegetation which serves as livestock forage. These woodlands also serve as a habitat for the tsetse-fly. For example, estimates indicate that over 60% of the total area of Tanzania is infested by tsetse-fly (ISC 1981). Manipulation of overstory woody plants offers one method of exploring vegetation overstory:understory relationships.

There has been interest in methods of controlling or reducing the density of the woody species of these areas to reduce tsetse-fly populations and increase herbaceous biomass (Van Rensburg 1953, Pratt and Gwynne 1977). Mechanical methods have been used to a limited extent (Pratt 1966, Harrington 1973, Madallali 1974). Fire has also been used, often in drier portions of East Africa rangelands (Thomas and Pratt 1967, Lugenja and Kajuni 1979). Herbicides have been used only to a limited extent (Parker and Parker 1966; Ivens 1971a, 1971b).

In spite of these attempts at reducing woody vegetation, the problem remains. Species of *Combretum* are especially resistant to control. Consequently, studies were initiated in 1984 to compare treatments for woody plant control and to determine response of herbaceous species to the control treatments.

Description of the Area

The studies were conducted at the Dakawa Pilot Ranching Unit, within Dakawa Ranch, in the Morogoro Region about 45 km northeast of the town of Morogoro, Tanzania. The ranch lies 6°–7° South and 37°–38° East at an elevation of 400 m. The area is generally flat-to-rolling with a few depressions near the river. There are 2 main soil types, sandy loams, which are vertisols on flat areas along the Wami River, and loamy sands, which are ultisols on rolling areas. Both soil types have good drainage (Hathout 1983).

The vegetation has been classified by Pratt and Gwynne (1977) as a woodland with *Isoberlinia, Brachystegia, Combretum, Terminalia, Dalbergia,* and *Commiphora* as the main genera of trees. Grasses are dominated by *Themeda triandra, Heteropogon contortus, Andropogon* spp., *Setaria* spp., *Hyparrhenia* spp., *Panicum* spp., and *Cymbopogon* spp. There are numerous annual forbs.

The climate as described by Pratt and Gwynne (1977) is a subhumid to semiarid eco-climatic zone with a rainy season from November to May and a long dry season from June to October (Fig. 1). The main ranch receives an average annual rainfall of 600 to 900 mm. An average total rainfall for 1981–1984 on the unit was 842.7 mm (Fig. 1). Mean annual temperatures recorded at Sokoine University of Agriculture in Morogoro, which receives similar weather to that of the Pilot Ranching Unit in Dakawa Ranch, are 30.2° C maximum and 18.8° C minimum.

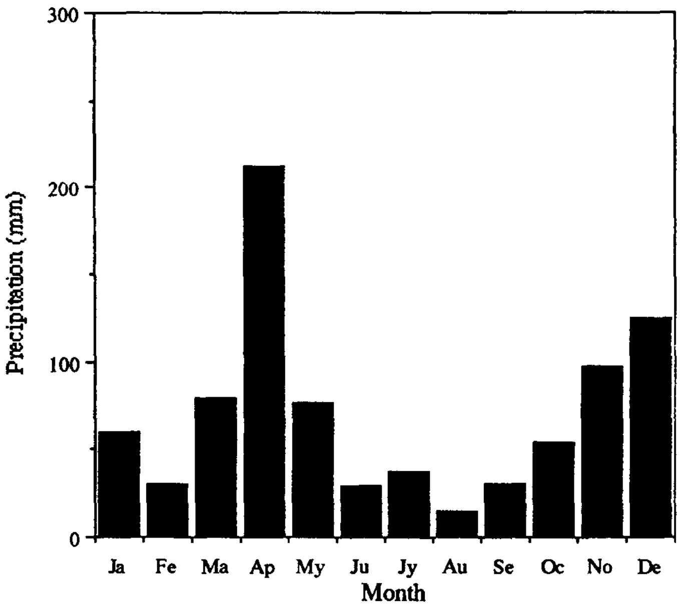

Fig. 1. *Monthly mean rainfall (mm) at Dakawa Pilot Ranching Unit, Morogoro.*

Study Sites

The 2 study sites selected are both located northwest of the main ranch headquarters. One of the sites is about 5 km from the main ranch headquarters on black sandy loam soil with good drainage. The area is occupied by *Combretum tenuifolium* and the understory is comprised mainly of *Andropogon gayanus, Setaria ciliolata, Themeda triandra,* and *Cymbopogon giganteus.* The second site is about 5 km from the black soil site and about 10 km from the main ranch headquarters on reddish-brown loamy sand soil and is occupied by a tree mixture of *Brachystegia/Isoberlinia* spp., *Combretum* spp., especially *C. molle,* and *C. binderanum, Terminalia,* and *Commiphora* spp. Grasses here include *Panicum infestum, Themeda triandra, Cymbopogon excavatus, Digitaria milanjiana,* and *Eragrostis* spp.

Methods

A fixed model, completely random design with 3 replications on each site was used for the study. Each replicate consisted of 15 × 20 m plots. Four replicates were treated just after the rainy season (June) and the other 4 were treated after the trees had sprouted following the dry season (December). Four treatments, including 3 methods of herbicide application: cut stump, frilling, ring barking, and a control were used.

Statistical analyses were done by standard analysis of variance procedures (Steel and Torrie 1980). The protected least significant difference (LSD) method (Carmer and Swanson 1973) was used to compare treatments and season means within sites.

Herbicide Treatments

In all treatments, Trioxone 100, a herbicide mixture of equal parts of the isoctylester of 2,4-D (2,4-dichlorophenoxy acetic acid) and the isoctylester of 2,4,5-T (trichlorophenoxy acetic acid) was used. The recommended mixture of 1 part trioxone to 50 parts of diesel oil was used to prepare the final solution for application. A paint brush was used in application of the herbicide in all treatments. Treatments applied just after the rainy season were carried out on 19 June 1984 on the reddish-brown soil site and on 20 June 1984 on the black soil site. Treatments after sprouting of the trees and just before the rainy season were applied on 6 December 1984, on both sites.

In each treatment, all *Combretum* species, which ranged from 2 to 20 cm in diameter, were treated 22.5 cm above soil level with enough herbicide to produce an overflow. For the cut stump treatment, the tree was completely removed and herbicide applied on the entire stump. Frilled trees had 6.5-mm cuts made around the trunks to which the herbicide was applied. Ring-barked trees had about 30 cm of bark removed around the trunk and herbicide applied into the ring. The control received no treatment. All treated stems were counted and recorded by species for each treatment.

Botanical Composition and Herbage Production

Herbage yield was determined on the reddish-brown soil site on 1 July 1985, and on 2 July 1985, on the black soil site using the "clipping" method in each treatment for both seasons. A 0.25-m² quadrat was used in the sampling operation. In each treatment plot, 2 randomly located quadrats were clipped to ground level for grasses and forbs, and only the usable leaves and twigs were harvested for shrubs. All material clipped was sorted by species.

Table 1. Mean mortality (%) by treatment and season for *Combretum* species by site.

	Treatment											
	Cut stump[1]			Frilling			Ring-barking			Mean		SE[2]
Species	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	
	Reddish-brown soil site											
Combretum binderanum	37.45	23.7	30.6	25.2	65.4	45.3	23.3	48.2	35.8	28.7	45.8	11.9
Combretum molle	68.3^{a}[3]	25.5^{b}	46.9	47.5^{ab}	34.4^{bc}	41.0	62.3^{ac}	52.0^{ab}	57.2	59.4^{x}	37.3^{y}	11.9
	Black soil site											
Combretum ternifolium	66.3^{a}	29.4^{b}	47.9	56.2^{ab}	27.1^{b}	41.6	69.2^{a}	30.0^{b}	49.6	63.9^{x}	28.9^{y}	11.8

[1]Treatment with herbicide (Trioxone + Diesel oil).
[2]SE = standard error of mean.
[3]Means in the same row followed by different superscripts (a,b,c) are significantly different ($P<0.10$) for dates within treatments. Treatment means are not significantly different ($P<0.10$). Overall means with different superscripts (x,y) are significantly different ($P<0.10$) between dates.

Samples were air-dried for 2 weeks and then weighed to the nearest gram. The resulting weights were used to compute the yield in kg per ha and the percent botanical composition for each species.

Mortality Determination for *Combretum* Species

To determine whether a tree was dead or alive, all treated *Combretum* trees were assessed visually for any signs of either live leaves, growth buds or sprouts. Trees without any of these structures, and having dead stumps or trunks, were counted as dead. Percent mortality for a species was computed based on the number dead in relation to the original number treated. Mortality for the June 1984 treatments was determined on 4 July 1985, on the reddish-brown soil site and on 5 July 1985, on the black soil site. Evaluation for the December 1984 treatments was done on 11 February 1986, on both sites.

Results and Discussion

Mortality of *Combretum* Species

All 3 *Combretum* species treated responded similarly ($P \geq 0.10$) to the 3 methods of herbicide application. This lack of differential treatment effect between cut stump and the other 2 methods (Table 1) may partially be explained by the observation of Carter (1974) that in cut stump treatment only the outside ring of the stump need be treated with the herbicide. In this case, therefore, the cut stump treatment would not be expected to differ from either frilling or ring barking in which the herbicide is applied to the outside ring after notching the trunk or removing the bark.

Season of herbicide application approached the significant level ($P \leq 0.105$) for *Combretum binderanum* mortality on the reddish-brown soil site. A significant season effect ($P \leq 0.05$) was observed with *Combretum molle* on the reddish-brown soil site, and *Combretum ternifolium* ($P \leq 0.01$) on the black soil site. For both these species, higher mortalities were recorded for the June rather than the December application (Table 1). It seems that soil moisture was still adequate in June for these species to allow translocation of the herbicide to the roots. The trees appeared to be water-stressed at the time of the December application. The tendency of *Combretum binderanum* to respond slightly better to the December application is not clear.

The treatment × season interaction approached the significant level ($P \leq 0.108$) for *Combretum binderanum*, that had responded differently to the cut stump and frilling treatments in June and December. Treatment means for June did not differ but for December applications, frilling resulted in a significantly higher mortality rate (65.4%) than that for the cut stump treatment (23.7%) but was not different from ring barking treatment (48.2%). Frilling had a significantly greater effect in December than in June (Table 1). Generally, the cut stump treatment showed seasonal differences compared to the frilling and ring barking treatments. The overall effects averaged over application times on the reddish-brown soil site indicated that *Combretum molle* (48.4% mortality) was more susceptible to the herbicide application than *Combretum binderanum* (37.2% mortality).

Herbage Production

Total herbage standing crop was not affected by the different treatments on each site. For standing crop on the black soil site on ring barking plots increased significantly compared to the control (Table 2). This response of forbs could be explained by higher mortality of *Combretum ternifolium* on ring barking plots in June than the other methods on this site. This mortality might have reduced competition for both light and soil moisture, which then favored the forbs.

On the black soil site the method × season interaction was significant ($P \leq 0.10$) for *Andropogon gayanus*. Herbage standing crop of *Andropogon gayanus* in the ring barking treatment differed significantly from that of the control in both seasons (Table 3). The difference in June could be explained by the reduced

Table 2. Mean herbage standing crop (kg • ha^{-1}) by treatment and season for different species on the reddish-brown soil site.

	Treatment														
	Control			Cut stump[1]			Frilling			Ring-barking			Mean		
Species	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	SE[2]
Panicum infestum	1173	1213	1193^{ab}[3]	1320	760	1040^{ab}	533	53	293^{a}	2360	1573	1967^{b}	135	900	580
Themeda triandra	1173	2427	1800	1253	3187	2200	2133	1280	1707	480	1720	1100	1260	2153	914
Other grasses	1080	973	1027	347	333	340	480	1147	813	0	5093	2547	477	1887	1727
Forbs	27	53	40	53	27	40	53	200	127	27	0	13	40	70	80
Shrubs	0	0	0	0	27	13	0	0	0	53	53	53	13	20	29
Total yield	3453	4667	4060	2973	4333	3653	3200	2680	2940	2920	8440	5680	3137	5030	1663

[1]Treatments with herbicide (Trioxone + Diesel oil).
[2]SE = standard error of mean.
[3]Treatment means averaged over dates in the same row followed by different superscripts are significantly different ($P < 0.10$).

Table 3. Mean herbage standing crop (kg • ha^{-1}) by treatment and season for different species on the black soil site.

	Treatment														
	Control			Cut stump[1]			Frilling			Ring-barking			Mean		
Species	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	SE[2]
Andropogon gayanus	10560^{ac}[3]	13347^{ab}	11953^{xy}	9067^{ac}	13960^{ab}	11513^{xy}	4960^{ac}	7213^{ac}	6087^{x}	21440^{b}	4053^{c}	12747^{v}	11507^{v}	9643^{v}	3674
Setaria sp.	4320	0	2160	3547	3453	3500	3107	3400	3253	1320	4827	3073	3073	2920	1850
Themeda triandra	0	306	153	1600	2320	1960	1467	0	733	613	3160	1887	920	1447	1499
Other grasses	0^{a}	360^{ab}	180^{x}	0^{a}	960^{ab}	480^{x}	0^{a}	0^{a}	0^{x}	0^{a}	1773^{b}	887^{x}	0^{v}	773^{x}	611
Forbs	173^{a}	0^{a}	87^{x}	147^{a}	1107^{a}	627^{xy}	0^{a}	0^{a}	0^{x}	3627^{b}	173^{a}	1900^{y}	986^{v}	320^{v}	788
Shrubs	0	2453	1227	0	0	0	0	0	0	0	0	0	0	613	867
Total	15053^{ab}	16467^{ab}	15760^{xy}	14360^{ab}	21800^{ac}	18080^{x}	9533^{b}	10613^{b}	10073^{y}	27000^{c}	13988^{ab}	20493^{x}	16488^{v}	15718^{v}	3442

Table 4. Mean botanical composition (%) by treatment and season for different species on the reddish-brown soil site.

	Treatment														
	Control			Cut stump[1]			Frilling			Ring-barking			Mean		
Species	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	SE[2]
Panicum infestum	40.8^{abc3}	32.4^{ab}	36.6	53.2^{ac}	24.0^{ab}	38.6	19.2^{ab}	3.6^{b}	11.4	82.7^{c}	33.0^{ab}	57.9	49.0^{x}	23.2^{y}	19.8
Themeda triandra	33.3	46.1	39.7	34.8	69.1	51.9	64.6	89.2	61.9	14.8	30.3	22.6	36.9	51.2	20.6
Other grasses	24.8	20.0	22.4	9.0	5.1	7.1	14.8	29.9	22.3	0.0	36.4	18.2	12.2	22.8	17.8
Forbs	1.1	1.5	1.3	3.0	0.9	1.9	1.4	7.4	4.4	0.8	0.0	0.4	1.6	2.4	3.0
Shrubs	0.0	0.0	0.0	0.0	0.9	0.5	0.0	0.0	0.0	1.7	0.3	1.0	0.4	0.3	0.7

[1]Treatments with herbicide (Trioxone + Diesel oil).
[2]SE = standard error of mean.
[3]Means in the save row followed by different superscripts (a,b,c) are significantly different ($P<0.10$) for dates within treatments. Treatment means are not signicantly different ($P<0.10$). Overall means followed by different superscripts (x,y) are significantly different ($P<0.10$) between dates.

Table 5. Mean botanical composition (%) by treatment and season for different species on the black soil site.

	Treatment														
	Control			Cut stump[1]			Frilling			Ring-barking			Mean		
Species	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	Mean	June	Dec	SE[2]
Andropogon gayanus	71.4	82.5	78.0	55.0	62.0	58.5	49.4	63.1	56.3	74.9	40.3	57.6	62.7	62.0	15.6
Setaria sp.	27.5	0.0	13.8	24.5	16.1	20.3	37.9	36.9	37.4	8.2	32.9	20.6	24.5	21.5	14.2
Themeda triandra	0.0	1.7	0.9	19.6	12.3	16.0	12.8	0.0	6.4	1.7	14.9	8.3	8.5	7.2	9.6
Other grasses	0.0^{a3}	2.0^{a}	1.0^{x}	0.0^{a}	5.1^{ab}	2.7^{x}	0.0^{a}	0.0^{a}	0.0^{x}	0.0^{a}	10.6^{b}	5.3^{x}	0.0^{v}	4.4^{w}	2.9
Forbs	1.1^{a}	0.0^{a}	0.5^{x}	0.8^{a}	4.4^{a}	2.6^{x}	0.0^{a}	0.0^{a}	0.0^{x}	15.2^{b}	1.3^{a}	8.3^{y}	4.3^{v}	1.4^{v}	2.8
Shrubs	0.0	13.8	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	4.9

[1]Treatments with herbicide (Trioxone + Diesel oil).
[2]SE = standard error of mean.
[3]Means in the same row followed by different superscripts (a,b) are significantly different ($P<0.10$)for dates within treatments. Treatment means in the same row followed by different superscripts (x,y) are significantly different ($P<0.10$). Overall means in the same row with different superscripts (v,w) are significantly different ($P<0.10$).

competition following the higher kill of *Combretum ternifolium* thus allowing more *Andropogon gayanus* to grow. The December application may have not been effective enough to allow more growth of this species than in the control.

Botanical Composition

In general, no species on the reddish-brown soil site differed significantly ($P<0.10$) in percent composition for the different treatments compared to the control (Table 4). However, *Panicum infestum* was consistently higher in composition for all treatments applied in June than for the December application. This difference could be attributed to the susceptibility of *Combretum molle,* which is more abundant on the site, to the June application of the herbicide allowing more light and soil moisture to be available to this grass species. Another reason may be that in June the reduced competition for soil moisture created by the reduction in *Combretum molle,* coupled with the light shading providing for the remaining trees, created an ideal environment for *Panicum infestum.* It behaves similarly to *Panicum maximum,* which grows in land cleared from forest and in grasslands with scattered trees where it tends to grow in light shade, under trees (Bogdan 1977).

A significantly lower amount of *Andropogon gayanus* was observed on the ring barking treatment compared to the control for December on the black soil site (Table 5). This difference may be explained by the smaller percentage of *Combretum ternifolium* killed during this application. As a result, the reduced competition for both light and soil moisture might have favored the other grasses such as *Cymbopogon giganteus* which increased at the expense of *Andropogon gayanus.*

Forbs had significantly higher composition in the June ring barking treatment than in the control. The higher mortality of the trees from this application apparently provided this increase. Other species differences between treatments compared to the control were largely due to the absence of the species in a particular treatment.

Woodland vegetation often forms a 2-phase pattern consisting of the trees with their associated vegetation and herbaceous vegetation of the interspaces (Whittaker et al. 1979). Responses of understory species to overstory reduction were somewhat inconsistent in this study. There was indication that *Andropogon gayanus* and *Panicum infestum* biomass and composition increased in response to overstory reduction, but definitive evidence was lacking. Better control of overstory, perhaps by hand clearing, would be required to obtain further information on overstory:understory relationships. Differences in tree mortality and herbaceous response to the treatments are likely the result of site differences. Caution should be used in applying results of this study to other sites.

Management Implications

Since the 3 methods of herbicide application did not differ in their effectiveness in the control of *Combretum* species, frilling would be more suitable for use than either cut stump or ring barking since it is both less laborious and faster. Although ring barking showed a slightly better response than the other 2, this method is more laborious than frilling and as Carter (1974) pointed out, ensuring that all the cambium strands are removed is difficult.

Considering that the dominant species on both sites, *Combretum molle* and *Combretum ternifolium*, were better controlled by June treatments than by those in December, and *Combretum binderanum* was not affected by season, it would be better to carry out the control operation on both sites in June to attain effective control of these species. It is also during this time that forage production from *Panicum infestum* and *Andropogon gayanus*, which are among the main forage species for cattle in the area, would be encouraged and could thus increase the carrying capacity of the ranch.

As the percent mortalities for all 3 *Combretum* species on the 2 sites were low (≤50%), it would be necessary to have a follow-up operation to control regrowth to maintain the tree stand at the desired density. Otherwise the area may revert to the original stand or experience an increase in tree density.

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