

Season Based Application of Bush Control Techniques for Unaddressed Bush Species (*Vachellia senegal*) in Borana Zone, Southern Ethiopia

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Abstract: The study was conducted to evaluate bush controlling techniques on encroaching bush species (*Vachellia Senegal*) in Miyo district of Borana zone for three consecutive years. A total area of 2.5 hectares of rangeland encroached by *Vachellia* species was replicated into two plots for each four seasons. Each plot was subdivided into five sub-plots to receive five treatments; cutting at 0.15m above ground 2, 4 D application on stump (T1), cutting at 0.15m above ground a mixture of 75% 2,4-D and 25% water application on stump (T2), cutting at 0.15m above ground kerosene application on stump (T3), cutting at 0.5m above ground debarking (T4) and no cutting (T5). Data on different parameters including basal and litter covers, soil erosion and compaction, dead and re-sprouted encroaching tree/shrub species were collected before and after treatment applications. The result indicated that for all seasons, different parameters were significantly influenced ($p < 0.05$) by the applied treatments. Among the tested bush controlling treatments, T1 was more effective in bush controlling in dry (78%) and cool dry (71%) seasons as compared to other treatments. Similarly in the dry season, the responses of T2, T3, and T4 in controlling *Vachellia Senegal* were 69%, 63% and 61% respectively. The result also showed that different bush controlling techniques were found to improve the basal and litter cover, species richness, species evenness, and biomass yield of rangeland. The evaluated techniques were also indicated in decreased soil erosion and soil compaction. Increased in basal cover and changed in vegetation structure of rangeland of bush thinned plots were related with reduction of encroaching canopy thickness and regenerated perennial herbaceous species. Due to better accessibility, cost effectiveness and friendly to environment T4; cutting at 0.5m above ground and debarking was recommended for pastoralist to be applied at dry season. Besides, reseeding important herbaceous species with enough periods of resting shall be considered for improving degraded rangelands such as less recovery potential of bush cover areas.

Keywords: Basal Cover, Bush Controlling, Rangeland, Grass and Non-Grass, Species Composition, Species Diversity

1. Introduction

Borana rangelands in the southern parts of the country were considered to be one of the best grazing lands [5]. However, these rangelands are experiencing increasing pressure from livestock and human populations, bush encroachment and tick infestation [2]. Mismanagement coupled with disregard of indigenous knowledge makes bush encroachment one of the major problems in many pastoral areas of Ethiopia. In Borana rangelands, where for century's episodic climatic events and the use of fire regulated

vegetation dynamics, the natural balance between grasses and trees has shifted and bush cover has become a major threat to pastoral grazing management. *Vachellia drepanolobium*, *Vachellia mellifera* and other *Vachellia* species are the dominant encroachers of southern Ethiopia [4, 6]. According to Gemedo, D. T. et al. [7], in the Borana rangelands, woody plant cover increased from 50% as reported in the late 1990s by Oba, G. Stenseth, N. C. and Lusigi, W. [11] to 60%. Bushes are transforming open grazing lands into impenetrable thicket-forming noxious trees/shrubs and suppressing desirable grasses and non-grasses through

competition, thus becoming unsuitable for browsing and grazing [14]. As the research [11] reported that bush encroachment in the Borana rangelands reduces livestock productivity and survival particularly during drought years, when forage scarcity is the greatest.

Local and international non-governmental organizations and some government departments are conducting range rehabilitation, involving hand clearing of woody species along highways and near settlements, on an experimental basis which is not successful. Nowadays, the successful results we brought in controlling two encroaching bush species namely: *Vachellia mellifera* and *Vachellia drepanolobium* made different NGOs (CARE, GPDI etc...) and GOs (zonal and district level pastoralist development offices, Pastoralist Community Development Project (PCDP)) to widely implement the best techniques in the vast rangelands of Borana. Similarly, promising result was attained by pouring 2,4-D over stumps and thoroughly debarking stumps of encroaching bush species like *Vachellia drepanolobium* and *Vachellia mellifera* soon after cutting at 0.15m above ground [4].

However, information about the effects of bush encroachment control techniques in terms of the responses by the encroaching bush species like *Vachellia Senegal* which are aggressive in nature to inhibit the growth of herbaceous vegetation under their canopy is lacking. Furthermore, information on controlling this bushes species through chemical and mechanical methods across the four prominent seasons in the Borana rangeland is poorly documented. Hence the objective of study was to determine the response of herbaceous species to different bush control techniques and to identify the best seasons and techniques for controlling *Vachellia Senegal* species.

2. Materials and Methods

2.1. Site Selection

The study was conducted in Miyo district, Borana zone of Southern Ethiopia. Based on the priority of the pastoral community and other stakeholders, top encroaching bush species for the district was selected. Selection of the encroaching tree/shrub species (*Vachellia senegal*) was based on their relative dominance over the district. During the project conduction, indigenous knowledge of the community on the nature of bush encroachment was considered through participatory approach. A total area of 2.5 hectors rangeland unit which was encroached by the target bush species was delineated soon after assessment and identification of the intended site.

2.2. Treatments and Experimental Design

The treatments were consist of cutting at 0.15m above ground + 2, 4 D application on stump (T1), cutting at 0.15m above ground + a mixture of 75% 2,4-D and 25% water application on stump (T2), cutting at 0.15m above ground + kerosene application on stump (T3), cutting at 0.5m above

ground + debarking (T4) and no cutting (T5). The experiment was laid out in a randomized complete block design with two replicates. The selected 2.5 hectare rangeland from the target district was laid out in twelve plots to accommodate five treatments across the four prominent seasons (4 seasons * 5 treatments * 2 replicates). Each of the treatment was laid out on a 25 m x 25 m land that was separated from each other with a border space of two meter. The plots were located adjacently and treatments were allocated randomly to the plots. The target species were marked during cutting process and the areas were fenced using locally available materials. About 25 ml of pure 2,4D, 25% diluted 2,4D and kerosene were used to apply on the stump of bush species.

2.3. Sampling and Measurements

Dry matter, basal cover, litter cover; herbaceous vegetation composition, density and frequency were assessed in 0.5m×0.5m quadrat. All vegetation attributes were collected prior to treatment application and at the end of the study period to see the effects of bush encroachment controlling action. The scores used for basal cover and litter cover were based on the criteria developed for semi-arid rangelands in southern Africa [3]. Dry matter yield of herbaceous species was determined after drying in oven at 105°C for 24 hours. Dead and re-sprouted bush species were recorded at the end of the study period.

2.4. Statistical Analysis

The dry matter, basal cover, litter cover and other vegetation attributes were sorted by treatment and seasons and considered as experimental units for data analysis in a randomized complete block design. The parameters were subjected to ANOVA, using the GLM procedure of SAS Version 9 computer software package [12]. Means were tested for significance using Least Significance Difference and differences were declared significant at $P < 0.05$.

3. Results and Discussion

3.1. Response of Bush Control Techniques on Herbaceous Structure

A total of 34 herbaceous species were identified in the bush control techniques applied plots (Table 1). Based on their life forms, 47% annual herbaceous and 53% perennial herbaceous species were identified. The result also indicated that plots applied with bush controlling techniques increased the botanical composition by 52% as compared to none applied (control) plots.

In the plots of bush controlling techniques, both highly and less desirable species had the highest proportion (38% and 38%) followed by desirable species (24%). Of the total herbaceous species identified, about 47% were grasses species. The result showed that higher proportions of botanical composition wererecorded inplots with bush control techniques applied than the control plots. In the study areas, from grass species *Aristida kenyensis* species were

highly dominated grass species. From 16 grass species recorded (Table 1), eleven species had highly desirable species, four had desirable and one had less desirable species. From the highly desirable groups of grass species *Cenchrus ciliaris*, *Chrysopogon aucheri* and *Chloris roxburghiana* were recorded highly in the bush thinned plots than unthinned plots. *Commelina Africana* was the highly desirable non-grass species that identified in the bush control treatment

applied plots. Among the herbaceous species recorded in the study plots *Ocimum forskalei* was common and dominated the plots, followed by *Aristida akenyensis*. This significant difference in botanical composition along treatments and control plot is due to the reduction of the impact of bush density on the growth of herbaceous species. Therefore, reduction of bush density has positive effect on the recovery of rangeland herbaceous species.

Table 1. Response of bush control techniques on botanical composition herbaceous species.

Scientific Name	Growth form	Life form	Desirability	2,4,D	2,4,DW	Kerosene	Debarking	Control
<i>Chrysopogon aucheri</i>	Grass	P	HD	1.38	0.67	0.77	1.75	0.00
<i>Actinopterys radiata</i>	Forbs	A	LD	0.55	0.00	0.00	0.00	0.00
<i>Digitaria milanjaniana</i>	Grass	P	HD	7.71	0.33	9.23	0.44	0.52
<i>Barleria spinisepala</i>	Forbs	P	D	3.31	3.01	3.85	7.89	8.85
<i>Commelina Africana</i>	Forbs	A	HD	0.55	1.00	0.38	0.88	0.52
<i>Ocimum forskalei</i>	Forbs	P	LD	41.32	47.83	36.54	15.35	15.63
<i>Plectranthus barbatus</i> Andr.	Forbs	A	LD	0.55	0.00	0.00	0.00	0.00
<i>Abutilon hirtum</i> (Lam.) Sweet	Forbs	P	HD	6.61	4.68	7.31	10.96	13.02
<i>Chlorophytum gallabatense</i>	Forbs	A	D	3.31	4.68	2.31	10.09	13.02
<i>Aristida kenyensis</i>	Grass	A	D	10.47	10.70	10.38	19.74	23.44
<i>Tetrapogon tenellus</i>	Forbs	A	LS	1.38	2.01	5.38	1.32	0.00
<i>Sporobolus pellucidus</i>	Grass	A	D	2.48	7.02	5.38	1.32	3.13
<i>Leptothrium senegalense</i>	Grass	P	HD	7.71	4.35	2.69	3.07	6.25
<i>Indigofera volkensii</i> Taub.	Forbs	P	D	0.28	0.00	0.00	0.00	0.00
<i>Chloris roxburghiana</i>	Grass	P	HD	0.55	0.00	0.38	1.75	0.00
<i>Setaria verticillata</i>	Grass	A	D	4.68	2.01	1.54	2.63	2.60
<i>Indigofera species.</i>	Forbs	A	LS	0.28	0.00	0.00	0.88	0.52
<i>Dactyloctenium</i>	Grass	P	HD	0.55	2.34	1.92	3.95	3.13
<i>Digitaria velutina</i>	Grass	A	D	3.86	4.01	7.31	11.84	6.77
<i>Osteospermum vaillantii.</i>	Forbs	A	LD	0.28	0.00	0.00	0.00	0.00
<i>Harpachne schimperii</i>	Forbs	A	LD	0.28	0.00	0.00	0.00	0.00
<i>Cenchrus ciliaris</i>	Grass	P	HD	0.83	0.67	1.54	0.44	0.52
<i>Cyperus species.</i>	Grass	P	HD	0.00	1.34	0.00	0.00	0.00
<i>Euphorbia crotonoides</i>	Forbs	P	LD	0.00	0.67	0.00	0.00	1.04
<i>Eragrostis species</i>	Grass	P	HD	0.00	0.33	0.00	0.00	0.00
<i>Bidens hildebrandtii</i>	Forbs	A	LD	0.00	0.67	0.77	0.00	0.00
<i>Macroculia species</i>	Grass	P	HD	0.00	1.67	1.92	0.00	0.00
<i>Chloris roxburghiana</i>	Grass	P	HD	1.10	0.00	0.00	0.00	0.00
<i>Bidens biternata</i>	Forbs	A	LD	0.00	0.00	0.38	0.88	1.04
<i>Sporobolus discosporus</i>	Grass	A	LD	0.00	0.00	0.00	0.44	0.00
<i>Partinium species</i>	Forbs	P	ND	0.00	0.00	0.00	2.19	0.00
<i>Cladostigma hildebrandtioides</i>	Forbs	P	D	0.00	0.00	0.00	0.44	0.00
<i>Chenopodium opulifolium</i>	Forbs	A	LD	0.00	0.00	0.00	0.44	0.00
<i>Bothriochloa insculpta</i>	Grass	P	HD	0.00	0.00	0.00	1.32	0.00

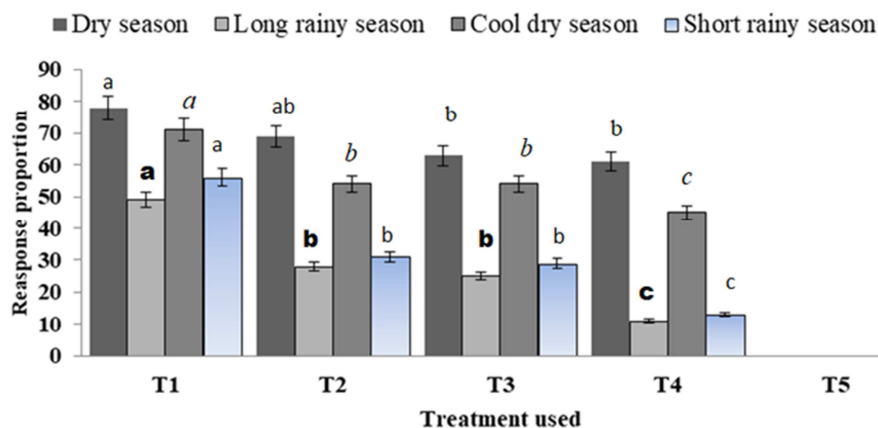


Figure 1. The response of *Vachellia senegalensis* to different treatments within four seasons.

NB: T1=cutting at 0.15m above ground + 2, 4 D application on stump, T2=cutting at 0.15m above ground + a mixture of 75% 2,4-D with 25% water application on stump, T3=cutting at 0.15m above ground + kerosene application on stump, T4=cutting at 0.5m above ground + debarking and T5=no cutting.

3.2. Response of *Vachellia senegal* to Different Bush Control Techniques Within Different Season

The result indicated a significant difference observed between different seasons and treatments that applied on the control of *Vachellia Senegal* bush species. The stump death of *Vachellia Senegal* was highest for T1 (cutting at 0.15m above ground + 2, 4 D application) in dry season (78%) followed by cool dry season (71%). The result indicated that the stump death of *Vachellia Senegal* was 78, 69, 63, and 61% for T1, T2, T3 and T4 respectively in dry season while it was 71, 54, 54 and 45% in cool dry season for T1, T2, T3 and T4 respectively. But stump death of *Vachellia Senegal* was showed lower response (less than 50%) for all treatments in both long and short rainy season except in T1.

This indicated that *Vachellia senegal* species could be controlled by using treatment 1 (cutting at 0.15m above ground + 2, 4 D) in the dry season as compared to the other treatments and seasons. A similar finding [4] showed that probability of mortality among woody species is highest in dry season.

3.3. Response of Bush Control Techniques on Basal and Litter Cover, and Soil Erosion and Compaction

Percentage of basal cover and litter cover were significantly ($P < 0.05$) different between bush controlling techniques and the control treatments. The basal covers of the plots with treatment of different bush controlling techniques were increased by 10.25% as compared to the control plots. The high basal cover in the treatment applied plots could be associated with reduced encroaching tree species densities which created a suitable condition for regenerate new grass and forbs species.

Table 2. Effect of bush controlling techniques on basal and litter cover, soil erosion and compaction.

Treatment	Basal Cover	Litter Cover	Soil Erosion	Soil Compaction
T1	30.35a	16.95	12.25c	31.05b
T2	30.25a	14.30	14.25bc	33.55b
T3	31.60a	13.70	12.30c	40.56b
T4	29.88a	13.73	18.08b	38.30b
T5	12.80b	17.20	33.20a	52.85a
C V	39.67	85.29	72.86	51.29
P-values	0.0001	0.89	0.0001	0.0001

NB: ¹abc Means in the same column without a common letter are different; T1=cutting at 0.15m above ground + 2, 4 D application on stump, T2=cutting at 0.15m above ground + a mixture of 75% 2,4-D with 25% water application on stump, T3=cutting at 0.15m above ground + kerosene application on stump, T4=cutting at 0.5m above ground + debarking and T5=no cutting.

The canopy gaps created by bush species removal are expected to result in increased herbaceous cover, diversity and abundance due to reduced competition for water and nutrients as well as increased availability of light [13]. In line with this finding, [9] found that non-encroached sites had a

higher grass cover than the bush-encroached sites. The Percentage of soil erosions and compaction were significantly different between treatment plots and control plots. It showed that soil erosion and compaction was decreased by 18.98% and 16.99% respectively due to different bush controlling treatments as compared to the control treatment. The reductions in soil erosion and compaction might be due to the increment in basal cover of herbaceous species that support soil particles by their above and ground biomass. This in turn increases water infiltration rates into the soil and decreases runoff [8].

3.4. Response of Bush Control Techniques on Species Richness, Diversity and Evenness

The results indicated that the treatment applied plots were showed significantly difference in herbaceous species richness ($P < 0.01$) and evenness ($P < 0.02$) while no significant differences observed in species diversity. The differences was observed at treatment plots due to manual thinning of less desirable bush species in the encroached site, which reduce competition with herbaceous species, at the same time enhancing the chance of propagation than the control treatment. The result indicated that the herbaceous species diversity was not significantly different ($P > 0.05$) from the control treatment due to applying bush controlling techniques. In species richness, T1 and T4 have the highest values followed by T2 and T3 and the least for T5. These could be due to bush encroachment effects. This finding indicated that grass diversity is negatively correlated with woody plant density which is in accordance with [1].

Table 3. Effect of bush controlling techniques on species richness, diversity and evenness.

Treatment	Species richness	Species diversity	Species evenness
T1	23a	2.78	0.38b
T2	20b	2.5	0.37b
T3	19b	2.49	0.50a
T4	23a	2.60	0.53a
T5	16c	2.20	0.31b
CV	22.3	35.6	25.3
P-values	0.01	0.69	0.02

NB: ¹abc Means in the same column without a common letter are different; T1=cutting at 0.15m above ground + 2, 4 D application on stump, T2=cutting at 0.15m above ground + a mixture of 75% 2,4-D with 25% water application on stump, T3=cutting at 0.15m above ground + kerosene application on stump, T4=cutting at 0.5m above ground + debarking and T5=no cutting.

3.5. Response of Bush Control Techniques on Dry Matter Yield

Total dry matter yields of herbaceous species were influenced by the treatments with different bush controlling techniques and control treatment. There were highly significance ($P < 0.01$) differences between other treatments and control in grass and forbs species dry matter yield. The

higher dry matter yield obtained except for the control treatment might be due to the increment in basal cover percentage related with regenerate herbaceous species. These herbaceous species are very important livestock feed resources in the rangeland ecosystem.

Table 4. Effect of bush controlling techniques on dry matter yield.

Treatments	Grass (t/ha)	Forbs (t/ha)	Total (t/ha)
T1	0.145a	0.173a	0.318a
T2	0.110a	0.160a	0.268a
T3	0.136a	0.169a	0.305a
T4	0.105a	0.158a	0.263a
T5	0.026b	0.082b	0.108b
CV	32.35	32.35	32.35
P values	0.01	0.01	0.01

NB: ¹abc Means in the same column without a common letter are different; T1=cutting at 0.15m above ground +2, 4 D application on stump, T2=cutting at 0.15m above ground + a mixture of 75% 2,4-D with 25% water application on stump, T3=cutting at 0.15m above ground + kerosene application on stump, T4=cutting at 0.5m above ground + debarking and T5=no cutting

3.6. Response of Bush Controlling Techniques on Socio-Economic Parameters

As listed in table 5, the socio-economic parameters were evaluated to compare the bush controlling treatments. The result indicated that T1 was more effective in bush control, followed T2, T3 and T4 while the inverse is true for their socio-economic values. Among the chemicals used, 2, 4 D is herbicide which has toxicity to human beings, animals and soil macro and micro-organisms. Therefore, 2,4D required highly careful in handling during application than other bush controlling treatments. Moreover 2,4D and kerosene are not easily assessable and are expensive. On the other hands, debarking techniques has no cost, easily accessible and friendly to environment. However, compering to other treatments it was less effective in controlling bush and required high man power. Because of these facts debarking techniques was recommended as appropriate bush controlling techniques for pastoralist in the study area. Botany sectors who have a capacity to afford (such as private sectors or investors) can use 2,4D and Kerosene carefully for its time saving and effective bush controlling.

Table 5. Responses of bush controlling techniques on socio-economic parameters.

parameters used	Types of treatments			
	T1	T2	T3	T4
Cost of treatment per hectores	\$19.8	\$14.9	\$8.5	No need
Accessibility of treatment	Has effort	Has effort	Has effort	effortlessly
Time of application per hectores	10 hours	10 hours	10 hours	48 hours
Man power needed per hectore	One adult	One adult	One adult	Six adult
Action to be taken to prevent side effect	Good Mask and gloves	Good Mask and gloves	Any Mask and gloves	No need
Care to be taken during application	Very careful	Very careful	Careful	No need
Average amount of treatments needed per stump bush	25 ml	25 ml	25 ml	No
Effectiveness of the treatment per plots	Very higher	Higher	higher	lower

NB: T1=cutting at 0.15m above ground +2, 4 D application on stump, T2=cutting at 0.15m above ground + a mixture of 75% 2,4-D with 25% water application on stump, T3=cutting at 0.15m above ground + kerosene application on stump, T4=cutting at 0.5m above ground + debarking and T5=no cutting.

4. Conclusions and Recommendations

The result showed that different bush controlling techniques were found to improve the basal and litter cover, species richness, species evenness, and biomass yield of rangeland. The evaluated techniques were also decreased soil erosion and soil compaction. Among the tested bush controlling treatments, T1 was more effective in bush controlling in dry and cool dry seasons respectively as compared with the other treatments. Similarly in the dry season, the responses of T2, T3, and T4 in controlling *V. Senegal* were 69%, 63% and 61% respectively. However, 2, 4 D is herbicide that has chemical properties and toxic to human beings, animals and soil macro and micro-organisms. Moreover 2,4D and kerosene are not well assessable and are expensive. On the other hands, debarking techniques has no cost, easily accessible and friendly to environment. Compering to other treatments it was less effective in

controlling bush and required high man power. Due to better accessibility, cost effectiveness and friendly to environment T4; cutting at 0.5m above ground and debarking was recommended for pastoralist to be used at dry season. But any sectors who have a capacity to afford (such as private sectors or investors) can use 2,4D and Kerosene carefully for its time saving and effective bush controlling. Besides, reseeding important herbaceous species with enough periods of resting shall be considered for improving degraded rangelands such as less recovery potential of bush cover areas.

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