EFFECTS OF FIRE AND MOWING ON MIXED THEMEDA - HETEROPOGON GRASSLANDS

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Abstract

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Effects of season and frequency of burn on the percent cover of *Themeda triandra, Heteropogon contortus* and `other grass species' were evaluated in experimental plots located in central coastal Queensland. The design examined 2 seasons of burn and 5 fire frequencies and used the separation of plots by mown strips to evaluate the effects of mowing. The plots were stratified according to soil type in an attempt to reduce the variance arising from site differences. Aditionally, general observations address the effect of grading on an adjacent abandoned fire break which passed through an extensive pure sward of *T. triandra* and the effects of drought on the spatial patterns of mortality for the species.

Late season burns reduced the cover of *T. triandra* and also decreased the total plant cover. The cover of both grass species was highest with triennial burns and the cover of *T. triandra* was high and *H. contortus* low with annual burns. The cover of other species was highest at fire frequencies of 4 and 5 years. Mowing reversed the relative dominance of *T. triandra* and *H. contortus* observed in the burnt plots and the cover of other species was high. The cover of *T. triandra* was more related to soil type than that of *H. contortus* and soil effects were greater with burning than mowing. After 10 years an essentially pure sward of *H. contortus* colonized the abandoned fire break graded through an essentially pure sward of *T. triandra* while there was no apparent differeence in the mortality of species with drought. The results are discussed in relation to conditions that would occur with normal management of grazing properties. It is concluded that change in dominance from *T. triandra* to *H. contortus* observed in native pastures is due to the grazing by livestock rather than a change in the fire regime.

Introduction

Cattle grazing throughout central and southern coastal Queensland mainly occurs on pastures composed of native species even where the trees have been removed. This land use has changed the species composition of the pastures with *Heteropogon contortus* (bunch speargrass gradually replacing *T. triandra* (Shaw 1957). However, while the existence of the change is obvious the reasons for the change are not. Cattle grazing in the region was always associated with burning to remove rank hamper and promote new growth. Tothill (1969) suggested that burning causd this change in pasture composition but he later found no change in pasture composition with burning (Tothill, 1974). This was interpreted by Walker and Tothill (1980) as indicating that *T. triandra* becomes dominant only in the absence of regular domestic animal grazing despite Tothill (1974) having recorded little change in either *T. triandra* or *H. contortus* with grazing. *Heteropogon contortus* changed little with grazing and *T. triandra* only decreased where grazing was combined with fertilising. His results do not indicate that grazing has caused the observed change in the relative abundance of the species as it occurred in the absence of fertiliser.

The effect of fire on the proportions of *T. triandra* and *H. contortus* was further investigated by Walker et al.(1983). They concluded that the proportions could be altered by fire by controlling the season and frequency of burns but the results are difficult to interpret. The measures were visual estimates of the proportion of the plot occupied by each species. Bare ground or other species were not considered and the measures for different treatments were obtained at different times of the year. The visual appearance of *H. contortus* varies with season and the grass is most apparent during flowering and seeding. The use of such a visual assessment where the treatment and assessment are linked seasonally introduces uncertainty as to whether seasonal effects are due either to the treatment or to the time and method of assessment. Also, as the results were analysed in terms of the ratio of the percent occurrence of the species change would not be detected where the amounts of each species increase or decrease in unison.

Walker et al. (1983) analysed their results as proportions because in experiments of this nature there is a confounding between fire frequency and time since burn. Burning is an `instantaneous' treatment and its effects are recorded as a change with time after the burn rather than being simply manifest as the amount of organic matter remaining after the fire. Heteropogon in plots burnt annually is present as a high density of young plants but after four years without burning it occurs as large plants at a relatively low density. Fire produces an initial impact but the effect of the treatment is expressed with time after the burn. The time required for full expression varies with fire frequency thus the significance of measures obtained at three years in a plot burnt every five years is difficult to ascertain. This confounding cannot be resolved with analysis of variance in a time x treatment analysis as the maximum age of the growth that can be recorded depends on the treatment.

There are two partial solutions to the above problem. One is to measure all plots one year after burning, thereby eliminating effects due to time since burn. The complication then is that unless the experiment is terminated by burning all plots at the same time this would introduce seasonal differences due to the seasonal application of treatments. The alternative is to obtain measurements when the time since burn equals the fire frequency. This gives the effects of the interaction between fire frequency and time since burn but does not give their separate effects.

The objective of this experiment was to further elucidate effects of fire on the performance of *T. triandra* and *H. contortus* growing in mixtures. The experiment used was that described by Walker et al. (1983). The approach used was to employ covariate analysis to remove effects due to site differences that existed within the fully randomised design. The plots were separated by mown strips, thus all experimental plots were bordered by grassland that had been treated similarly throughout the experiment. The mown areas provided a reference for changes within the plots as well as a basis for comparison between the effects of mowing and burning. The problem of confounding between fire frequency and time since burning was approached by attempting to obtain measurements in plots where the time since burn equalled the fire frequency.

Methods

The experiment has been described previously (Walker et al. 1983). Briefly, a fully randomised factorial experiment of season (4) and frequency (6) of burn was established in 1971 in grassland adjacent to The Plains homestead in the Shoalwater Bay Training Area in central coastal Queensland. Three meter wide fire breaks between the 20 x 20 m plots were created and maintained by mowing. The fire breaks were mown approximately four times each year around March, July, October and December.

The composition of the grassland was almost exclusively *T. triandra* and *H. contortus* growing in mixtures with compositions that ranged between virtually pure swards of each species. The grassland had been burnt annually or biennially for 6 years prior to the experiment. Grazing in this period was limited to native macropods and a few feral horses and cattle. Grazing during the experiment was restricted to the native macropods. The area had previously been part of the house paddock on a cattle grazing property.

The fire frequencies were 0, 1, 2, 3, 4 and 5 years. The season of burn were early (first opportunity), mid dry, late dry and after the first wet season rains. These roughly equate to July-August, September, October-November and November-December but plots in all treatments were burnt as late as December. There were 4 replicates for each treatment.

For this study the zero burn treatment was omitted and the seasonal treatments reduced to two by grouping early with mid dry and late dry with the latest seasonal burns. Five replicate plots were selected from these treatments such that the time since burn equalled the fire frequency. This was not always possible given the structure of the experiment and the relationship between fire frequency and time since burn for the plots was:

Frequency 1, 5 plots with 1 years growth.

Frequency 2, 2 plots with 2 and 3 with 1 years growth.

Frequency 3, 5 plots with 3 years growth.

Frequency 4, 4 plots with 4 years growth.

Frequency 5, 2 plots with 4 and 3 plots 3 years growth.

The organisation of the sampling was therefore 5 fire frequencies, 2 seasons and five replicates giving a total of 50 plots.

In November 1980 the cover percent of *T. triandra, H. contortus* and `other species' was determined by superimposing a regular grid of 100 points spaced at 150 x 100 mm centres on the plots and visually recording whether a point was directly above a green leaf of any of the species. Two samples were obtained in each plot at points mid way along and 1 m inside the northern and eastern plot edges. Paired measurements were also taken in the centre of the mown strip separating the plots. The nearest edges of the paired samples in the burnt and mown sites were approximately 2 m apart. The centre of the mown strip was sampled as this avoided paths that had been impacted by vehicles.

The initial experimental design was fully randomized but there were marked gradients throughout the experimental area related to site conditions rather than treatment. Walker et al. (1983) stratified the plots according to soil type to obtain significant treatment effects. Three methods were used here to remove site differences. The ratio of *T. triandra* to the total plant cover for the mown strips was used as a covariate. The mown strips had been treated similarly for ten years and so differences between plots presumably reflected site differences. The measured plots were aggregated into 10 blocks based on proximity without regard to season of burn. The closer the plots the more they tend to be similar. Also, the plots were stratified according to soil type which gave 4, 3, 2 and 1 replicates for the 4 soil types.

Transformations were applied to some measurements to improve the statistical analysis. The other species were log transformed after adding 1 to all cover estimates to remove a skewed distribution. However, while log transformations improved the significance they did not alter the conclusions thus results are presented in the untransformed state where possible to aid interpretation.

The effect of grading was observed on an abandoned fire break just inside the boundary of the Shoalwater Bay Training Area. This site, approximately 9 km west of The Plains homestead, had a similar history to the above experimental area except that the grazing pressure would always have been much lower. The treatment was a single pass of a grader blade through an essentially pure sward of *T. triandra* in an open paperbark woodland. This removed all plants and a thin layer of top soil. Subsequently the area would have been burnt as frequently as possible (generally every second year) early in the season as part of the fire management in the training area. Grazing by native macropods and feral animals would have been very low.

General observations of mortality associated with a drought that killed trees as well as grasses were made throughout the training area in late 1980's. The most distinct pattern was in intact native vegetation at a stream line associated with a gradient from deep soil on a plain to shallow soil at an incised drainage line. Grass on the plain was effectively pure *T. triandra* (the location was close to the grading example above) but this species was absent adjacent to the drainage line where *H. contortus* was dominant. There was a distinct boundary between *T. triandra* and *H. contortus* along the low slope

Results

The cover data were analysed for fire frequency and season effects as a completely randomized design using an analysis of variance both on their own and using measures from the mown sites as covariates. They were also analysed for fire frequency effects when grouped into the 10 blocks based on proximity. All analyses gave similar results. Significance levels were improved by blocking but were generally highest when using the covariate. Results for fire frequency and season from the covariance analysis are given in Table 1.

Fire frequency effects were significant for all plant components (Table 1). The cover of *T. triandra* was high at frequencies of 1 and 3 years. The cover of *H. contortus* was highest at a frequency of 3 years and low at 1 and 5. The cover of other species was highest at frequencies 4 and 5. The total cover was constant apart from frequency 3 where the high individual yields of both *T. triandra* and *H. contortus* combined to produce a high total cover. The ratio of *T. triandra* to *H. contortus* was high with annual burns but was constant for the other fire frequencies.

Seasonal effects were significant for *T. triandra* but not the other measured components. This species is disadvantaged by late season burns. This effect is reflected in the levels of total cover hence late season burns prevent the other species from taking advantage of the suppression of *T. triandra*.

In Table 2 the mean condition for all burning treatments is compared with that for mowing. These results were derived from the analysis of the plots when grouped into the 10 blocks based on proximity. The covers of *T. triandra* and *H. contortus* in the mown strips are approximately half and double that in the burnt plots respectively. Mowing effectively reversed the dominance of the species.

The projected cover of live plant material is higher when mown than when burnt despite the higher plant biomass in burnt plots. The combined contribution by the two dominant grasses is equivalent in both treatments but there is a greater contribution by other species in mown plots.

The data were blocked according to the distribution of soil types given by Walker et al. (1983) and analysed for soil and soil + fire effects using generalized linear modelling. The design for this analysis gave the replication for the soil types Db3.52, Db1.12, Dr2.12 and Gn3.12 (after Northcote 1979) of 1, 2, 3 and 4 respectively. The results are summarised in Table 3.

The main feature of the results is the high variability as the percent variance accounted for is generally low. However, effects of soil type were better expressed with burning than mowing, the exception occurring with other species. In burnt plots soil type accounted for around 10 to 20% of the variance and fire frequency for an additional 10 to 20%. In mown plots, the percent variance accounted for by soil type varied from zero to 15.

The effect of soil type on *T. triandra* is high and relatively independent of mowing or burning. The effect on *H. contortus*, and on total plant cover, is much lower. Soil type affects the performance of *T. triandra* more than *H. contortus* but has little effect on total cover.

Cover of *T. triandra* was high on soil types Gn3.12 and Dr2.12 and low on types Db1.12 and Db3.52 with both fire and mowing. The pattern was similar for *H. contortus* with mowing but reversed with fire, however, the effects with mowing were weak. In consequence the ratios of *T. triandra* to *H. contortus* showed the same pattern of response to soil type as *T. triandra*.

Ten years after a single denudation the graded strip was colonised by a virtually pure sward of *H. contortus* while the surrounding pasture remained a virtually pure sward of *T. triandra*. The denuded area was colonised by *H. contortus* despite the remoteness of a seed source and the original grassland being essentially pure *T. triandra.*

With drought plants of all grass species died where they occurred on patches of shallow soil. There was no apparent difference in the mortality of species. The killing of all grasses on the shallow soils on the low slope adajcent to the drainage line had the effect of causing the boundary of live *T. triandra* plants to move further upslope by around 25m onto deeper soil.

Discussion

The seasonal effects (time of burn) are similar to those presented by Walker et al. (1983) but the use of cover data rather than ratios allows examination of the cause of the change. Late season fires disadvantage *T. triandra* but have no effect on *H. contortus* relative to early burns. However, these data do not indicate whether this difference is due either to a decline in the population of *T. triandra* or to limited growth of existing plants. Regardless of the cause, the other species were unable to compensate for this change and late season burns were disadvantageous in reducing plant cover relative to early burns.

The fire frequency effects obtained here are also similar to those observed by Walker et al (1983) but again the analysis of cover data rather than ratios provides further insights. The covers of both *T. triandra* and *H. contortus* were maximal at a fire frequency of 3 years but *T. triandra* had an additional peak at 1 year. Plant cover in the plots benefited from triennial burns with the existing species composition but *T. triandra* was promoted and *H. contortus* disadvantaged by annual burns. The other species were promoted by a lack of fire.

Both grass species benefit from fire in that it tends to exclude other species. Both species maintain maximum cover after three years without burning and the cover of other species is then at its lowest. Neglecting consideraions relating to recruitment of *T. triandra*, a three year burning frequency appears best for the maintenance of mixed Themeda/Heteropogon grasslands.

The benefit to *T. triandra* and disadvantage to *H. contortus* by annual fires appears to arise because regrowth of *T. triandra* after burning is through growth of existing plants whereas *H.*

contortus largely regenerates from seed. Existing plants with well developed root systems have a competitive advantage over seedlings. This benefit would probably only persist while plant numbers were not limiting to growth as recruitment of *T. triandra* was not observed with the annual burning regime.

The effect of mowing was pronounced in benefiting *H. contortus* and disadvantaging *T. triandra*. Mowing also benefited other species although it cannot be determined whether this is due to mowing or the absence of fire.

The effect of grading is significant in two regards. It demonstrates the colonising ability of *H. contortus* on bare earth even where there is little local availability of seed. The seed presumably arrived via the grader or animals. It also demonstrates the competitive equality of these species in the presence of fire once they are established. Neither species had crossed the boundary of the cut and invaded the others territory. Results for the effects of fire frequency indicate that *T. triandra* should be at a competitive advantage with the given burning regime but this advantage in cover had not been translated into territorial advantage.

The results presented here and by Walker et al. (1983) indicate that the relative proportions of *T. triandra* and *H. contortus* can be altered by controlling the burning regime but the question remains as to whether the changes observed in paddocks either have occurred by these means or can be implemented in practical land management. Experimental implementation of desired burning regimes is difficult because of seasonal variations in conditions for both burning and the production of fuel. The implementation of such regimes in grazed paddocks would be more difficult because of the increase in scale and the modification of the fuel by animals.

Paddocks generally do not burn uniformly and are only burnt following good seasons when there is an accumulation of rank hamper. Some potential fuel is consumed while other material is lodged through trampling. For practical reasons fires are only intentionally lit early in the season when the soil is moist or after appreciable rain. Given these constraints the results here suggest that the observed change in pasture composition from *T. triandra* to *H. contortus* dominance is not due to fire as fire benefits both species relative to other grasses. However, *T. triandra* is disadvantaged by regular defoliation and can be completely replaced where the soil is denuded over a sufficiently large area. Grazing can produce such an effect, particularly during droughts, and would therefore appear to be the main cause of the observed change in species dominance.

This conclusion is equivalent to that of Groves and Williams (1981) who suggest that the observed change in pasture composition from *T. triandra* to *H. contortus* dominance is due to the combination of fire and grazing. The dominance of *T. triandra* occurred with fire being a normal environmental variable. The changes in environment that occurred with european settlement were a change in fire regime and / or an increase in the level of grazing. Given that the observed changes in species dominance do not appear to be due to changes in the fire regime the conclusion is that they are due to the increased grazing. Whether such changes would have occurred with grazing given the exclusion of fire cannot be evaluated.

The above conclusion requires some qualification. The burning experiment ran for 10 years which is appreciable compared with the life cycle of *H. contortus* but short when compared with the longevity of *T. triandra. Heteropogon contortus* reproduces proflically through seed but seedling regeneration of *T. triandra* was only observed after burning at very low fire frequencies and then at very low density compared with *H. contortus*. Given that the plants of *T. triandra* must eventually die it can be surmised that *H. contortus* would eventually become dominant given any frequent burning regime. Whether this either could or would occur in practice cannot be asessed because of the lack of knowledge of the regeneration and longevity of *T. triandra.*

Some insights into the natural distribution of *T. triandra* and *H. contortus* are given by the patterns of plant mortality associated with drought. As with fire both species perform similarly in the environmental conditions. However, applying the observations following grading, any denuded area would be rapidly recolonised by *H. contortus.* There would be no recruitment of *T. triandra*, as least in the short to medium term. Their relative distributions largely derive from the life cycles of the plants with *T. triandra* performing as a long lived perrenial having limited reproduction and *H. contortus* as a short lived species with copious seed prodiction and associated recruitment. *Heteropogon contortus* is best suited to colonising disturbed areas and hence is promoted over *T. triandra* by grazing.

Caution is needed when extrapolating these results as the biology of *T. triandra* is not constant over its range nor is its ecological environment. Plants of *Themeda triandra* in central Queensland have very low production of small seeds. Comparatively those in Victoria have high numbers of large seeds and there is no ecological equivalent to *H. contortus* for it to compete with. Themeda triandra in southern Australia appears to have a much greater colonising role than in northern Australia. Dense and extensive colonisation by *T. triandra* occurred in paddocks ploughed for tree planting in the Bombala region in southern NSW and *T. triandra* colonises disturbed soils along roadsides on the Great Dividing Range at Omeo. The evolutionary development of a species depends on other species that occur in its environment as well as the physical conditions and the response of a species to disturbance reflects its evolutionary development.

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Table 1 Effects of the frequency and season of burning on the percent cover of *Themeda triandra, Heteropogon contortus* and other species as assessed using analysis of variance with the covariate Log(T.tria / Total) from the mown plots. The means presented are adjusted for the covariate.

Component	Fire Frequency (years)					
	1	2	3	4	5	SE
T. triandra	29.1	18.6	27.6	14.9	18.9	4.4
H.contortus	8.2	15.2	18.6	15.8	11.3	3.9
Log(T.aus/H.con)	1.56	-0.08	-0.45	-0.06	-0.21	0.64
Other Species	1.2	3.1	0.9	4.3	4.3	1.6
Total	38.6	36.8	47.1	34.9	34.6	3.3
Component	**Season**					
	Early	**Late**	**SE**			
T. triandra	25.0	18.6	2.75			
H. contortus	13.4	14.3	2.45			
Log(T.tri/H.con)	0.78	0.05	0.4			
Other Species	2.2	3.4	1.0			
Total	40.6	36.2	2.06			

Table 2 Treatment means of percent cover for the mown and burnt plots.

Component	Treatment	
	Burnt	Mown
T. triandra	21.8	11.0
H. contortus	13.8	25.4
Other Species	2.8	8.2
Total	38.4	44.5

Table 3 Percent variance in plant cover accounted for by soil type and fire frequency using generalized linear regression.

Component	Treatment		
	Mown	Burnt	
	Soil	Soil	Soil + Fire
T. triandra	15.0	20.9	41.6
H. contortus	4.5	9.7	21.8
T.tri/Total	12.3	20.4	29.5
Other Species	12.8	7.2	20.7
Total	0.9	9.5	30.3