SOME OBSERVATIONS ON ECOLOGY AND CONTROL OF WOODY WEEDS ON MULGA LANDS IN NORTHWESTERN NEW SOUTH WALES

C. W. E. MOORE*

ABSTRACT

Control of woody weeds in mulga lands must be achieved through management practices based on a knowledge of the ecology of the communities and species. A promising method appears to be through the use of fire as a management tool, but much research is needed on the effects of fire on both the woody species and the herbaceous stratum, especially the perennial grasses. The role of goats and the use of herbicides for control of woody weeds are briefly discussed.

INTRODUCTION

In the present context the term "mulga community" refers to any plant community in which mulga (*Acacia aneura*) is the dominant or co-dominant species. In his vegetation map of western New South Wales, Beadle (1948) shows *A. aneura* as the dominant Alliance (to use the more acceptable term, rather than Beadle's "Association") over the greater part of the country west of the Darling River and north of Broken Hill, while east of the Darling is another important mulga community, the *Eucalyptus populnea—A. aneura* Alliance. James (1960) has mapped the mulga communities in greater detail for the Paroo-Upper Darling Region.

According to Condon (1961) and James (1960), the mulga communities occur on the brown acid soils of both the level alluvial country of coarse texture and the undulating and hilly country; on deep sands and sandhills; and on the skeletal soils of the far west.

The soils supporting mulga communities, as mapped by Northcote (1966, 1968) are shown in Table 1. The Red Earths are the dominant soils of the mulga lands of the region, with relatively minor occurrences of the other soils.

TABLE 1

Soils supporting mulga communities as classified and mapped by Northcote (1966, 1968)

Soils with Uniform Texture Profiles	Soils with Gradational Texture Profiles	Soils with Contrasting (Duplex) Texture Profiles
(i) Loamy soils with weak podzolic development	Red Earths	Crusty and loamy soils with red clayey subsoils. Alkaline reaction trend
Shallow, dense loamy soils *Um 5.41*	(a) Alkaline reaction trend *Gn 2.13*	(a) No A2 horizon *Dr 1.13*
(ii) Loamy soils with minimal development	(b) Neutral reaction trend *Gn 2.12*	(b) Sporadically bleached A2 horizon *Dr 1.33*
Coherent and shallow loamy soils *Um 1.4*		
(iii) Sandy soils of minimal development		
(a) Coherent sands, shallow varieties *Uc 1.43*		
(b) Siliceous sands *Uc 1.2*		

*CSIRO Rangelands Research Unit, Riverina Laboratory, Deniliquin 2710.

Of the many species of woody plants occurring in the region, relatively few have become troublesome weeds. The most common are *Eremophila mitchellii* (buddah, often referred to as false sandlewood in Queensland), *E. sturtii* (turpentine), *Dodonaea attenuata* (hopbush), and *Cassia nemophila* (punte). Other species, including mulga itself, may reach pest proportions under some conditions; e.g. *Dodonaea lobulata* and *Cassia artemisioides* on lithosols and skeletal soils, *Eucalyptus populnea* in depressions and creek lines. Another widespread weed in mulga lands causing serious loss of productivity is *Bassia birchii* (galvanised burr).

D. attenuata reaches maximum development on deep sandy soils (sands to sandy loams), whereas *Eremophila* spp. and *C. nemophila* are more prominent on the finer textured red soils, especially where soil erosion has exposed the B horizon.

In the mulga lands control of unwanted species must be based on an understanding of the ecology of the weeds, and of the species with which they are to be replaced. There is limited scope, however, for more direct action in certain circumstances, through the use of mechanical or chemical methods of control.

A prerequisite to the application of ecology in the management of the mulga lands is an understanding of the causes of the present condition of the vegetation and soils. Though there is little (if any) experimental evidence available, there can be no doubt that the changes which have occurred during the past 120 years have been due to the direct or indirect effects of the activities of European settlers. The general sequence of events, with some indication of the interacting factors and complexity of the situation, has been described elsewhere (Moore 1969, 1971).

VEGETATION CONDITION AND TREND ON SELECTED SITES

Quantitative studies within the region are inadequate to give an overall picture of the present condition of the vegetation, and indeed even within an area of about 560 ha selected for detailed study about 60 miles northwest of Cobar, much remains to be done. A significant part of this area is typical mulga woodland, and within it,

TABLE 2

Total numbers of trees and shrubs in three transects each 10 m wide, of total length 573 m (1970, 1971) in a sample of A. aneura *woodland 60 miles northwest of Cobar*

Size Class	Height (cm)	*Acacia aneura*	*Cassia nemophila*	*Dodonaea attenuata*	*Eremophila longifolia*	*Eremophila sturtii* + *E. mitchellii**	*Pimelea microcephala*	Total
1	0–59	12	217	527	39	27	5	827
2	60–119	22	108	96	20	24	2	272
3	120–179	12	91	27	12	22	5	169
4	180–239	10	21	65	8	4		108
5	240–299	9	4	23		1		37
6	300–359	8		11		1		20
7	360–419	3		3				6
8	420–479	5		2				7
9	480–539	2						2
10	540–600	6						6
Total		89	441	754	79	79	12	1454
Mean Number:								
	Per Hectare	155	770	1317	138	138	21	2538
	Per Acre	62	308	527	55	55	8	1015

* Because of the difficulty in separating these two species in the absence of flowers they are grouped under one heading.

Other species recorded in transects include *Callitris columellaris* (1 individual, class 10), *Grevillea striata* (2 individuals > 600 cm), *Eremophila latrobei* (1 individual, class 2), *Myoporum deserti* (3 individuals, 2 in class 2, 1 in class 3), and an unidentified shrub (1 individual, class 1).

belt transects 10 m wide are being established to study the tree, shrub, and herbaceous strata. Data are available only for the tree and shrub components for 573 m of transect. The transect is divided into sub-plots 10 m × 10 m, and numbers and heights of trees and shrubs are recorded on each sub-plot.

By far the greatest number of individuals occur in the first three height classes, indicating current active colonisation by woody species. There is a dense population of shrubs, especially *Cassia nemophila* and *Dodonaea attenuata*, many of which will be eliminated by competition; but it is reasonable to assume that the shrub density will for a long period influence the development of the herbaceous stratum.

In an area of even greater shrub density, the owner of the property tried the effect of pushing the mulga and other shrubs at the end of 1967, with a view to improving the growth of herbaceous species. Early the following year, it was evident that the treatment had been temporarily successful, but that removal of the larger trees and shrubs had greatly increased the growth rate of the remaining shrubs, and had provided conditions favourable for the germination and establishment of a new population of the more aggressive species, especially *Acacia aneura*, *Dodonaea attenuata*, and *Cassia nemophila*.

To study the effect of the treatment on the herbaceous stratum, and also to determine whether rapid degeneration could be prevented, two sites, each 180 × 230 m, were chosen for studying the effects of fire on the vegetation. At Site 1 the dominant species was originally *A. aneura* with an understory of shrubs, while at Site 2 the dominant shrubs were *C. nemophila*, *D. attenuata* and *Eremophila* spp., with scattered *A. aneura*.

Each site was fenced to exclude domestic stock, and 20 plots each 40 × 20 m were established, with 10 m borders between plots, and 20 m borders between plots and fences. On each plot 8 permanent quadrats, each one m^2, and a 40 m permanent line transect along the centre, were established.

Numbers of seedlings and "established" woody species, heights of "established" plants, lists of herbaceous species, and estimates of total ground cover of herbaceous species are being recorded for the quadrats. Numbers and heights of all woody species are recorded on the line transects. It is difficult to determine when an individual has become established, but in general the distinction between seedlings and established plants is made when two or more leaves have developed, and the plant is 2 cm or more in height. At this stage the plant is still susceptible to short periods of drought, and in some species to frost, and many may die.

Because of the large quantity of fallen timber (especially mulga) on the plots, with consequent large differences between plots in the amount and type of fuel, it was decided that at the first opportunity the whole area would be burnt to clear the plots as much as possible prior to applying different burning treatments. Although conditions were far from ideal, both areas were burnt where possible on April 18, 1970.

There have been violent fluctuations in numbers of seedlings of *Dodonaea attenuata*, while those of *A. aneura* and *C. nemophila* have decreased greatly. A gradual increase occurred in the number of established plants of these three species, whereas the populations of *Eremophila* spp. have remained stable. Differences in the shrub populations of the two sites are clearly seen. Fluctuations in seedling numbers are due chiefly to deaths through drought and low winter temperatures, as well as the change in status from seedling to established plant.

Burning in April 1970 greatly reduced the number of shrubs. This was accompanied by an increase in their mean height, which is accounted for chiefly by a reduction in the number of small plants. Between August 1970 and September 1971, increase in shrub numbers was due mainly to the development of a new population, but in part to regeneration from the base of some plants whose tops were completely destroyed. The substantial increase in mean height over this period may be due to rapid growth as a result of reduced competition, perhaps augmented to some extent by release of available nutrients in the ash.

TABLE 3

Total number of seedlings (S) *and established shrubs* (E) *in 160 m² quadrats*
Plots burnt 18.iv.70

Species		SITE 1						SITE 2					
		June* 1969		June 1970	March 1971	April 1971	August 1971	March** 1972	June* 1969		June 1970	March 1971	April 1971	August 1971
Acacia	S			37	5	8	8	0			0	0	1	0
aneura	E	31		58	65	75	70	76	0		3	3	4	3
Cassia	S			82	5	12	4	0			142	5	17	2
nemophila	E	42		44	55	63	45	57	122		123	160	166	165
Dodonaea	S			89	7	67	46	0			424	6	111	74
attenuata	E	49	BURN	87	97	97	119	127	60	BURN	80	85	91	110
Eremophila	S			0	0	0	0	0			0	0	0	1
longifolia	E	9		8	10	8	8	5	5		7	5	4	5
E. sturtii +	S			0	0	0	0	0			0	0	0	0
E. mitchellii	E	1		1	1	1	1	1	19		12	17	18	21

* Seedling counts not made.
** No data were collected on Site 2 on this occasion.

TABLE 4
Total number of shrubs and mean heights (cm) on 20 line transects each 40 m long along centre of plots. Plots burnt 18.iv.70

Species		SITE 1			SITE 2		
		June 1969	August 1970	Sept. 1971	June 1969	August 1970	Sept. 1971
Acacia aneura	No.	84	51	101	26	12	12
	Ht.	48	124	175	53	99	300
Cassia nemophila	No.	101	33	33	419	148	189
	Ht.	30	46	114	43	58	145
Dodonaea	No.	98	37	54	167	83	158
attenuata	Ht.	25	43	107	58	91	170
Eremophila	No.	36	13	17	19	9	5
longifolia	Ht.	28	28	155	41	56	122
E. sturtii +	No.	14	12	4	94	45	32
E. mitchellii	Ht.	25	33	53	81	109	267
Hakea sp.	No.				6	4	5
	Ht.				48	56	142
Acacia murrayana	No.				1		2
	Ht.				109		241

BURN

TABLE 5
Frequency of grasses (based on 160 m² permanent quadrats for each site) and percentage ground cover of all herbaceous species at 2 sites

Species		June 1969	April* 1970	June 1970	March 1971	April 1971	Sept. 1971	March** 1972
Amphibromus	Site 1	0		0	0	0	0	0
caricinus	Site 2	0	0	0	1	1	1	
Aristida	Site 1	3		0	1	3	4	4
contorta	Site 2	8	3	0	1	5	4	
A. browniana	Site 1	0		1	3	3	0	0
	Site 2	2	0	1	4	1	0	
A. jerichoensis var.	Site 1	22		8	33	39	37	36
subspinulifera	Site 2	13	2	0	14	24	19	
Chloris	Site 1	0		0	0	0	0	0
acicularis	Site 2	0	0	0	0	1	1	
Danthonia	Site 1	6		4	9	6	4	4
bipartita	Site 2	4	3	3	9	8	5	
Digitaria	Site 1	0		0	0	1	0	0
coenicola	Site 2	0	0	0	0	0	0	
D. brownii	Site 1	0		0	0	1	0	0
	Site 2	0	0	0	0	0	0	
Enneapogon spp.	Site 1	0		0	0	2	1	1
	Site 2	1	0	0	1	1	0	
Eragrostis	Site 1	32		33	36	35	36	38
eriopoda	Site 2	10	11	9	14	13	13	
E. lacunaria	Site 1	36		18	27	26	25	25
	Site 2	23	15	11	16	19	18	
Neurachne	Site 1	9		8	8	9	10	10
mitchelliana	Site 2	9	10	9	10	12	11	
Panicum simile	Site 1	0		0	1	1	0	0
	Site 2	3	2	2	0	0	0	
Paspalidium	Site 1	0		0	0	0	0	0
gracile	Site 2	0	0	0	1	1	1	
Sporobolus	Site 1	0		0	0	0	0	0
carolii	Site 2	1	0	0	0	0	0	
Stipa setacea	Site 1	38		39	43	33	33	31
	Site 2	96	82	86	88	83	78	
Tripogon	Site 1	22		11	7	17	13	13
loliiformis	Site 2	7	0	4	3	7	9	
Mean % cover of all	Site 1	25		13	5	15	16	11
herbaceous species	Site 2	17	16	11	5	15	11	

* No record for Site 1.
** No record for Site 2.

At each site the most frequent grasses are *Aristida jerichoensis* var. *subspinulifera*, *Eragrostis eriopods*, *E. lacunaria*, *Neurachne mitchelliana*, *Stipa setacea*, and *Tripogon loliiformis*. Apart from *Stipa setacea*, grasses are more frequent at Site 1 than at Site 2.

During the period June 1969 to March 1972 there have been few changes in the frequency of the grasses, the most notable being an increase in *A. jerichoensis* var., a slight increase in *E. eriopoda*, and decreases in *E. lacunaria*, *S. setacea* and *T. loliiformis*.

Total ground cover varies with seasonal conditions, but shows an overall deterioration during the period. At no time has the quantity of ground fuel been adequate for burning over the whole area.

The data in Table 5 should not be interpreted as indicating an effect of fire on the herbaceous vegetation. The burns at the two sites in April 1970 were far from uniform because of the uneven distribution of ground fuel. Only a few quadrats at each site were burnt, so that changes in the ground flora cannot be attributed to the effect of fire. The data should rather be considered in relation to seasonal conditions. Accurate rainfall data for the two sites are not available, but records at other sites show less than average rainfall for 1970 and 1971, with particularly dry winters in both years.

A well-known effect of fire is its effect on the seed of some shrubs, resulting in subsequent germination. Thus, fires at certain times of the year may induce germination of unwanted species. Limited observations suggest that this is unlikely to cause serious difficulties except where excessive quantities of woody fuel have accumulated—e.g. a fallen mulga or ironwood (*Acacia excelsa*). A burning log may have three effects:

(1) if the log is small and burns quickly, soil temperatures may not be increased to the extent required to affect germination;
(2) if the log is larger, and the fire lasts longer, soil temperatures may be increased to the extent required to encourage germination;
(3) if the log is large and produces a hot fire which lasts for a long time, the soil is baked and all seed destroyed.

In the two areas burnt on April 18, 1970 where logs of all three classes occurred, records have been kept of the germination of shrubs. In classes (1) and (3) few or no shrubs have germinated, while in class (2) *Dodonaea attenuata*, *Acacia aneura*, and *Cassia nemophila* seedlings have been observed. By far the greatest number of seedlings were *D. attenuata*, with only occasional occurrences of the other two species. Six permanent m^2 quadrats were established on each site on typical class (2) areas, and the number of seedlings of each species have been recorded on several occasions.

During the first twelve months after germination, mortality of *Dodonaea* seedlings was severe, the numbers decreasing to about one-third of the original. In the subsequent twelve months numbers of seedlings have been maintained at this level. If the use of fire can be incorporated into management systems, it may be anticipated that seedlings developing after the initial burn will be eliminated by subsequent burning.

Further study of the effects of fire on the shrub and herbaceous strata on these plots is dependent on the development of adequate ground fuel, preferably perennial grasses. Since the initial burn in 1970 rainfall has been inadequate for the development of the herbaceous stratum, illustrating the general problem in the use of fire in low rainfall regions.

FIRE AS A MANAGEMENT TOOL

The role of fire in the maintenance of open woodlands with a good cover of perennial grasses in the herbaceous stratum has been discussed elsewhere (Moore, 1969, 1971), and there seem to be good grounds for believing that changes in fire

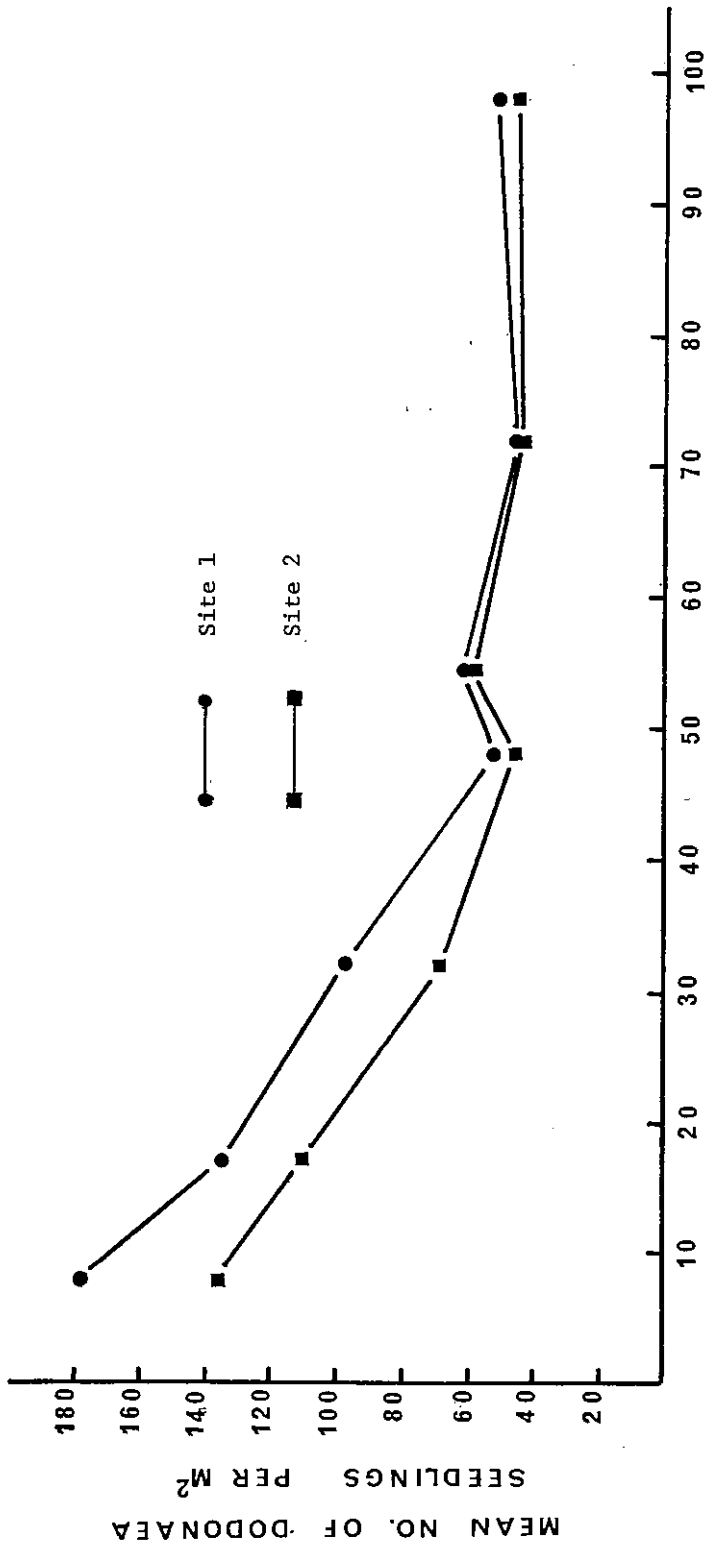

FIGURE 1

Changes in seedling populations of *Dodonaea attenuata* with time on 6 m² permanent quadrats located in sites where small logs and a slow fire can be expected to increase soil temperature and encourage germination.

frequency associated with settlement and the introduction of domestic stock have been in part responsible for the changes in the vegetation. Further, the changes in the vegetation have in themselves resulted in changes in fire frequency and effectiveness.

Associated with the general degeneration of the vegetation, particularly the reduction in the perennial grass component, has been widespread soil loss, by both wind and water erosion. This has frequently resulted in the complete removal of the surface soil, and the exposure of the B horizon. Excessive run-off, combined with unsuitable conditions for germination and establishment, make regeneration of perennial grasses and other herbaceous species slow and difficult, even when all stock are removed. General observations in an area of 570 hectares unstocked for three years indicate that regeneration of the herbaceous stratum is in fact inhibited by kangaroos and a small herd of feral goats.

When small areas (0.4 to 4 hectares) are enclosed, some regeneration of the herbaceous stratum may soon be evident, but there are violent fluctuations in ground cover, even over short periods, and equally great variability within the enclosures.

It may therefore be necessary in many situations to modify the soil environment to provide better moisture penetration and more suitable conditions for germination and establishment of seedlings before a burning programme becomes practicable. In March 1972 a tine pitter was used on some areas to determine whether changing the soil environment would be beneficial and practicable. No data have yet been collected on these sites, and it is not yet known whether reseeding with either native or exotic species will be necessary.

A number of factors will influence the effectiveness of fire in the control of woody species, and subsequent regeneration of the herbaceous stratum. These include

(1) season of burn;
(2) meteorological conditions at time of burning;
(3) occurrence and effectiveness of rain after burning;
(4) quantity and type of fuel;
(5) type of fire (e.g. ground fire or crown fire);
(6) time of introduction of stock after the burn.

Little information is currently available in relation to any of these factors, but available evidence suggests that effective control of mature shrubs is most likely to be achieved by a slow ground fire during the autumn-winter period.

It is not possible to assess the long-term effects of burning on the basis ofa single experimental burn, and it will be necessary to undertake long-term experiments to determine frequency of burning. However, it is considered that this aspect is best deferred until the appropriate season and type of fire have been determined.

Autecological studies of both woody and herbaceous species will provide information on such aspects as germination and establishment, effects of seasonal conditions on growth and production, reaction of herbaceous species to grazing and water stress —all of which are directly relevant to studies of burning and its application in management.

If fire can be shown to be effective in the control of woody species, a number of managerial problems will be evident. Since burning depends on the existence of adequate ground fuel (essentially dry grass), the grazier will have to decide whether to destroy the available feed in an area to achieve shrub control, or whether it is reasonable to defer burning for a further period. To develop sufficient fuel and to ensure recovery before restocking, the area may have to be left unstocked for an unknown period, dependent on rainfall, both prior to and after the burn. Thus it may be necessary to consider substantial increases in property size to permit burning. There will inevitably be a risk of soil erosion on burnt areas if recovery of the herbaceous stratum is delayed for a long period.

CONTROL BY GRAZING ANIMALS

Shrub weeds not palatable to domestic stock (sheep and cattle) may be palatable to other herbivores. The general opinion amongst graziers is that prior to the appearance of myxomatosis in the region about 1950, shrub densities were much less than at present, due to seedlings being eaten, and many mature plants being ringbarked by rabbits. However, rabbits prefer grasses and herbs, and tend to eat all available stock feed before eating the shrubs.

More recently considerable publicity has been given to the possible use of goats for the control of woody species. Wild goats are common in the region, but it is apparent that the goat population is inadequate to exert an appreciable effect on the control of shrubs.

Some graziers have rounded up herds of wild goats and confined them on small areas with a view to achieving shrub control. Observations made on one such area indicate that goats in sufficient numbers (about 2.5 per hectare) will exert appreciable control of some species, e.g. *Eremophila longifolia*, *C. nemophila*, *D. attenuata*, *D. viscosa*, *Hakea* sp., *Capparis mitchellii*, and *Geijera parviflora*, while others are apparently not palatable, e.g. *D. lobulata*, *Eremophila mitchellii*, *E. sturtii*, and *Myoporum deserti*.

Thus heavy grazing by goats might be expected to provide control of some weed species, possibly eliminate valuable herbaceous and browse species for sheep and cattle, and provide opportunities for other weed species to increase in density when competition is reduced. Campbell *et al* (1962) have stressed the paucity of critical studies of the effects of goats on the vegetation, and cite cases where goats did not graze the grass (Edwards, 1948); where they ate only the inflorescences of the grasses (Wilson, 1957); and where grasses provided the main part of the diet (Irvine, 1941; Hornby and van Rensburg, 1948). Further detailed studies of the effect of goats under controlled conditions are required before their role in weed control can be assessed.

Before goats could be effectively used for weed control, considerable capital expenditure for provision of new fences, upgrading existing fences, and additional watering points would be necessary.

HERBICIDES

Though costs prohibit the use of herbicides on a large scale in the mulga lands, chemical control of one or more species in limited areas may be desirable.

At least the majority, if not all the weed species can readily be killed by basal bark spraying with 2,4,5-T in diesel oil or power kerosene.

Experiments designed to assess the effect of foliar sprays using 2,4,5-T in water on *D. viscosa* have shown that this method can be effective, provided all the foliage is wetted. The most effective concentration appears to be 0.3% active ingredient, with addition of a wetting agent. In an initial trial, shrubs of widely varying age and size were treated using a knapsack spray, and at this concentration there was 100% kill.

A large-scale field trial employing 0.3% a.i. applied at 955 l/ha (84 gal/ac) using a boom spray appears to give about 99% kill. A final count of dead and living shrubs has yet to be made.

CONCLUSIONS

In the more favourable regions, mulga will recolonise actively (see Table 2 and Table 3 Site 1), and in fact may be as much a problem to the grazier as the more generally recognised woody weeds. In more arid regions, where mulga does not regenerate readily, it will be necessary to develop methods of encouraging germination

and establishment. A major research need is the determination of the site potential for a mulga climax and how to maintain it under grazing, at the same time suppressing undershrubs and maintaining maximum cover of perennial grasses.

To achieve this objective we urgently need autecological studies of shrubs and perennial grasses; development of methods of regenerating the herbaceous stratum; studies of the role of fire in the control of shrubs and in the maintenance of a perennial grass cover; and studies of the role of goats in the control of woody species.

REFERENCES

BEADLE, N. C. W. (1948)—"The Vegetation and Pastures of Western New South Wales with Special Reference to Soil Erosion." Government Printer: Sydney.

CAMPBELL, Q. P., EBERSOHN, J. P., and VAN BROEMBSEN, H. H. (1962)—Browsing by goats and its effect on the vegetation. *Herbage Abstracts* **32**: 273-275.

CONDON, R. W. (1961)—Soils and land form of the Western Division of New South Wales. *Journal of the Soil Conservation Service of New South Wales* **17**: 31-46.

EDWARDS, L. C. (1948)—Some notes on the food of goats. *East African Agricultural Journal* **13**: 221-223.

HORNBY, H. E., and VAN RENSBURG, H. J. (1948)—The place of goats in Tanganyika farming systems. I. In deciduous bushland formation. *East African Agricultural Journal* **14**: 94-98.

IRVINE, L. O. F. (1941)—The major veld types in the Northern Transvaal and their grazing management. Quinquennial Report, Toowoomba Pasture Research Station, Warmbaths, Transvaal. (mimeo).

JAMES, J. W. (1960)—Erosion survey of the Paroo-Upper Darling Region. *Journal of the Soil Conservation Service of New South Wales* **16**: 185-206.

MOORE, C. W. E. (1969)—Application of ecology to the management of pastoral leases in northwestern New South Wales. *Proceedings of the Ecological Society of Australia* **4**: 39-54.

MOORE, C. W. E. (1971)—Ecology and pasture management in northwestern New South Wales. "*Chiasma*" **9**: 83-86.

NORTHCOTE, K. H. (1966)—Atlas of Australian Soils, Sheet 3. Sydney-Canberra-Bourke-Armidale Area. *CSIRO Australia.* Melbourne University Press.

NORTHCOTE, K. H. (1968)—Atlas of Australian Soils, Sheet 10. Central Australia. *CSIRO Australia.* Melbourne University Press.

WILSON, P. N. (1957)—Studies on the browsing and reproductive behaviour of the East African dwarf goat. *East African Agricultural Journal* **25**: 138-147.