RESEARCH ON CHEMICAL CONTROL OF BITOU BUSH IN NEW SOUTH WALES

John Toth[A], Paul J. Milham[A], Ildiko Meszaros[A], C. Jill Kaldor[A], Robert N. Fullerton[B] and Frank Burrows[C]
[A]NSW Agriculture, Biological and Chemical Research Institute, Rydalmere, NSW 2116
[B]Department of Environmental Biology and Horticulture, University of Technology, Broadway, NSW 2007
[C]School of Biological Sciences, Macquarie University, North Ryde, NSW 2109, Australia

Summary Bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) is an introduced woody perennial that has invaded most native plant communities on the sandy coast of NSW. Bitou bush is highly invasive with the bioclimatic potential to grow in a continuous coastal belt from northern Queensland to south-eastern South Australia. Since 1985 NSW Agriculture has been developing chemical strategies for selective control of bitou bush. This paper reports ten years' research including results of: hand spraying several herbicides at different rates, and the effects of additives and sea-water; aerial spraying Roundup and Brush-off separately and in mixtures at different rates, in different volumes of water, and the effect of additives and spray-droplet size. Treatment effects were assessed by monitoring foliar damage to bitou bush and/or to one or more common, native, perennial plants.

INTRODUCTION

Bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata* (L.) T. Norl.) is a woody perennial native to South Africa. Herbarium records of the occurrence in Australia (Weiss 1986) show that the first specimen was collected at Stockton, near Newcastle, on the central coast of New South Wales (NSW) in 1908. It is possible that seed was introduced in ships' ballast. No further records occur until 1950 when a specimen was collected from an experimental area of the Soil Conservation Service of NSW at Port Macquarie on the north coast of NSW. From 1946 to 1968 bitou bush seed was sown widely on the central and north coast of NSW by the Soil Conservation Service and companies extracting titanium from sand (Weiss 1986).

The potential bio-climatic range of bitou bush is continuous from Cooktown (Queensland) to Cape Jaffa (South Australia). The range also includes scattered, high rainfall, frost free, discontinuous areas on the south and south-west of the continent (Howden 1984). Seed dispersal is the main mechanism by which bitou bush spreads. The reported faunal vectors include birds (Davies 1982) and foxes (Meek personal communication). Birds are the presumed cause of satellite infestations kilometres from the source. By 1982, 660 km of the NSW coastline was infested (Love 1984). We estimate that bitou bush now infests 90% of the sandy coastline of NSW, i.e. an area >70 000 ha.

A typical infestation commences above the high-tide level on the foredune with wind-pruned, scattered bushes. On the inland side of the dune's crest the plants develop to 2–3 m tall and 3–4 m in diameter. The infestation reaches maximum intensity on the inland toe of the foredune, where it may replace the native vegetation. The intensity declines further inland; however, bitou bush is a vigorous competitor in the understorey of adjoining banksia, eucalypt and casuarina woodlands. In these situations it scrambles into the canopy, overgrowing shorter trees. These characteristics place bitou bush among the 12 most invasive terrestrial weeds in Australia (Anon. 1992). It is a major threat to the biodiversity of the coastal ecosystem, having invaded more than 20 national parks and nature reserves (Toth *et al.* 1993).

Love and Dyason (1984), recommended that chemical and biological control techniques be developed for bitou bush. Responsibility for biological control was taken by ANZECC and for chemical control by the (then) NSW Department of Agriculture. In this paper we report the results of experiments on chemical control conducted from 1985 to 1996.

MATERIALS AND METHODS

A hand-held spray-gun powered by liquefied petroleum gas (LPG) was used to apply herbicide mixtures (Toth and Smith 1984). The herbicides tested include: Ciba-Geigy Code No. GGA-131036, dichloropicolinic acid (Lontrel®, a.i. 30%), fosamine (Krenite®, a.i. 42%), glyphosate (Roundup®, a.i. 36%), metsulfuron methyl (Brush-off®, a.i. 60%) and triclopyr (Garlon®, a.i. 60%). Each chemical was applied at least three rates.

Additional experiments using Roundup and Brush-off included: mixtures of the two chemicals; the effect of substituting sea water for fresh water; and, comparison of the Pulse® with Monsanto Code No. MON8169.

All treatments were applied to bitou bush and some treatments to at least one of the following native plants: *Casuarina glauca* (swamp oak), *Leptospermum laevigatum* (coastal teatree), *Leucopogon parviflorus* (coastal beard heath), *Acacia longifolia* var. *sophorae* (coastal wattle), *Banksia integrifolia* (coastal banksia), *Monotoca elliptica* (coastal heath) and *Lomandra longifolia* (mat rush). Every treatment was applied to

Table 1. Typical results from herbicide screening study, 1985 to 1998[A]

Herbicide treatments[B]		Foliar desiccation of bitou bush[C] (%)		
Trade name (a.i., %)	Rate	2	4	8
Brush-off (metsulfuron methyl, 60%)	0.25 g L^{-1}	30	80	100
	0.50	60	90	100
Ciba Geigy GGA 131036	1.0 g L^{-1}	30	70	SG
Garlon (triclopyr, 60%)	1:40	40	70	SG
	1:20	60	80	SG
Krenite (fosamine, 42%)	1:20	20	AG	AG
	1:10	40	AG	AG
Lontrel (dichloropicolinic acid, 30%)	1:50	30	75	SG
	1:20	60	100	100
Roundup (glyphosate, 36%)	1:50	80	100	100
	1:30	100	100	100

[A] A total of 15 trials was conducted at Moruya, Jervis Bay and Port Kembla.
[B] Herbicide mixtures applied at ~400 L ha^{-1} using an LPG powered, hand spray-gun (Toth and Smith 1984).
[C] Each value is the mean of scores by two observers, on four plants per treatment, rounded to the nearest 5%. AG–all plants growing, SG–surviving plants growing.

four plants of each selected species. For each plant, the height and circumference was measured as well as the volume of spray used. The symmetry was also scored. Experiments have been conducted each year from 1985.

A helicopter applied Roundup (1–9 L ha^{-1}) and Brush-off (10–150 g ha^{-1}). Low-drift nozzles (CP Products Co., Mesa, Arizona, USA) were used to deliver 15–60 L of spray ha^{-1} and Micronaires to deliver 1–30 L ha^{-1}. Treatments included: wetting agents and penetrants, substitution of a synthetic carrier for water and use of commercial mixtures of glyphosate and metsulfuron methyl (Trounce® and Cut-out®).

There were four sites: Jervis Bay, Port Kembla, Hawks Nest and Yamba. Experiments have been conducted each winter since 1989, with the exception of 1990. Plants of various species were tagged on transects for the assessment of herbicide effects.

Foliar damage was scored by two independent observers on several occasions during the year after treatment in all experiments. A score of 0% = no desiccation and 100% = desiccation of the whole canopy. At each assessment the average score was calculated for each species.

RESULTS AND DISCUSSION

Hand spraying Six herbicides were tested as candidates on bitou bush based on existing herbicide selectivity data for other woody perennial plants: Ciba-Geigy Code No. GGA-131036, Lontrel, Krenite, Roundup, Brush-off and Garlon. In this study a total of 15 trials was conducted at Moruya, Jervis Bay and Port Kembla between 1985 and 1988. Herbicides which either failed to control bitou bush (Table 1) or caused severe damage to adjacent native plants were excluded from further testing. Only Roundup and Brush-off proved sufficiently selective. The results also indicated that there may be a large, seasonal variation in the herbicide tolerance of bitou bush and of some native plants (Toth 1989). Calculations based on spray volume and bush geometry showed that the LPG powered, hand-held, spray-gun delivered 400 L ha^{-1}.

Time of application

Bitou bush To explore the possibility that herbicide sensitivity of bitou bush may vary seasonally, we applied either Roundup or Brush-off in a series of 16 experiments, which were commenced at approximately six-weekly intervals. During the two year study it became clear that some of the herbicide treatments were acutely toxic regardless of season. The concentrations of these treatments were decreased, e.g. the maximum concentration of Roundup from 1:50 to 1:100 (v/v) and of Brush-off from 0.5 to 0.1 g L^{-1}. All 16 time-of-application experiments were located at Bherwerre Beach in the Jervis Bay National Park.

The results (Table 2) show that bitou bush is at least twice as sensitive to Roundup in winter, shortly after peak flowering, than during the summer. No seasonal pattern emerged for Brush-off because the treatments (Table 2) were all too toxic. Summer applications of Brush-off, using high pressure spraying equipment that puts out 5000–10 000 L ha^{-1}, give control that is just as reliable as the same treatment applied during winter (Ken Hayes personal communication); but again the results throw no light on seasonal variation in sensitivity, because the rates of Brush-off used (0.5–1.0 kg ha^{-1}) are acutely toxic to bitou bush. For example, to apply these rates using the LPG spray-gun would require mixtures containing 1.25–2.50 g Brush-off L^{-1}.

Native plants By the end of the first year of the time-of-application study on bitou bush, it had become obvious that the optimum time of year for spraying, and the preferred chemical, could depend on seasonal changes in the tolerance of native plants. We therefore conducted two experiments, one during summer and the other during winter in which five native plant species were sprayed with either Roundup or Brush-off. Three rates of each chemical were used. One criterion for selection of the rates was that the lowest rate should be sufficient to kill bitou bush were it applied at the least suitable time of year (Table 2). These rates explore the safety margin between killing bitou bush and damaging native plants.

Summer applications of the herbicides were more damaging than the same rates applied in winter (Table 3). The effects varied with species and herbicide. The order of increasing tolerance to glyphosate was: coastal teatree<coastal heath<mat rush<coastal banksia<coastal wattle. The corresponding order for metsulfuron methyl was: coastal heath<coastal banksia<coastal teatree»mat rush<coastal wattle. These results show that winter is the optimum time of spray application for the selective control of bitou bush.

Table 2. Typical results for summer and winter herbicide trials on bitou bush[A].

Herbicide treatments[B]		Mortality[C] (%) Time of application	
Herbicide	Rate	Summer	Winter
Roundup			
(v/v)	1:50	70	100
	1:100	0	100
Brush-off			
(g L^{-1})	1.0	100	100
	0.25	100	100

[A] Typical results for the summer and winter members of a series of trials commenced at approximately six weekly intervals during a two-year period, at Bherwerre Beach, Jervis Bay National Park.
[B] Herbicide mixtures applied at ~400 L ha^{-1} using an LPG powered, hand, spray-gun (Toth and Smith 1984).
[C] Proportion of plants dead one year after spraying, rounded to the nearest 5%.

Spray additives

Penetrants One objective of our research has been to minimize the quantity of herbicides used, because the fate of these materials in the dune environment is unknown. Penetrants such as Pulse, an organosilicone compound, are known to approximately double the transport of Roundup into leaves (Turner 1985). Anecdotal evidence indicated that Pulse may have a similar effect with Brush-off.

The cause of the difference in herbicide tolerance of bitou bush and native plants is unknown. Therefore we tested the penetrants on both bitou bush and coastal teatree. The latter is abundant and moderately susceptible to both Roundup and Brush-off (Table 3).

The penetrants tested, Pulse and a Monsanto code numbered product (MON 8169), at least halved the lowest killing rate of both herbicides for bitou bush. Both penetrants were equally effective; consequently we present typical results with and without penetrant (Table 4). The herbicide tolerance of coastal teatree was also reduced by the addition of penetrants in both summer and winter (Table 4). This indicates that penetrants may prove useful in reducing spray rates; however, further research on selectivity is warranted.

Table 3. Tolerance of five species of native plants and bitou bush to summer or winter herbicide treatments.

Plant name	Summer (s) or winter (w)	Foliar desiccation[A] Roundup (v/v)[B]			Brush-off (g L^{-1})[B]		
		1:50	1:40	1:30	0.25	0.5	1.0
B. integrifolia	s	20	30	30	70	75	90
	w	0	10	10	5	10	25
Coastal teatree	s	10	20	30	30	40	55
	w	0	10	10	15	20	25
Coastal heath	s	0	10	25	100	100	100
	w	0	0	5	5	20	20
Coastal wattle	s	5	10	15	5	10	15
	w	0	0	5	0	0	0
L. longifolia	s	15	30	40	50	55	70
	w	5	15	25	0	0	0
Bitou bush	s	30	70	95	100	100	100
	w	100	100	100	100	100	100

[A] Each value is the mean of scores by two observers, on four plants per treatment, four months after herbicide application, rounded to the nearest 5%.
[B] Herbicide mixtures applied at ~400 L ha^{-1} using an LPG powered, hand spray-gun (Toth and Smith 1984).

Sea water Storm damage to the canopy of bitou bush is frequent and the role of sea water in this phenomenon has been a matter of speculation. Furthermore, there are many beaches where fresh water is not readily available for spraying. Consequently we sprayed bitou bush with marginally toxic rates of Roundup and Brush-off diluted with either fresh or sea-water.

The data (Table 5) support three inferences. Firstly, Roundup may be slightly less toxic when mixed with sea water. This is not surprising given the well known antagonism between polyvalent cations and glyphosate. Secondly,

Table 4. Typical effect of penetrants on herbicide toxicity to bitou bush and coastal teatree.[A]

Herbicide treatments[B]	Summer (s) or winter (w)	Foliar damage[C] (%)			
		Bitou bush		Coastal teatree	
		± Penetrant			
Herbicide Rate		–	+	–	+
Roundup (v/v)					
1:50	s	60	–	10	–
1:200	s	15	70	0	15
1:200	w	40	100	0	10
1:400	w	–	100	0	0
Brush-off (g L^{-1})					
0.25	s	100	–	50	–
0.04	s	50	95	0	30
0.04	w	75	100	0	30
0.02	w	–	95	0	20

[A] Typical results for the summer and winter members of a series of trials commenced at approximately six weekly intervals during a two-year period, at Bherwerre Beach, Jervis Bay National Park.
[B] Herbicide mixtures applied at ~400 L ha^{-1} using an LPG powered, hand spray-gun (Toth and Smith 1984).
[C] Assessments were made four months after herbicide application. No difference was observed between the effects of Pulse and MON 8169, so results were pooled as + penetrant. All values are rounded to the nearest 5%.

Table 5. Effect of using seawater on toxicity of Roundup and Brush-off to bitou bush.[A]

Herbicide	Spray mixtures: Rate	Spray mixtures: Fresh (F) or seawater (S)	Foliar desiccation[B] (%): 4 (months after application)	Foliar desiccation[B] (%): 12 (months after application)
Roundup				
(v/v)	1:200	F	70	70
		S	50	50
	1:120	F	90	90
		S	85	85
Brush-off		F	70	90
(g L^{-1})	0.05	S	80	100
	0.10	F	100	100
		S	100	100
No herbicide	–	F	0	0
		S	0	0

[A] Herbicide mixtures applied at ~400 L ha^{-1} using an LPG powered, hand spray-gun (Toth and Smith 1984).
[B] Each value is the mean of scores by two observers, on four plants per treatment rounded to the nearest 5%.

Brush-off may be slightly more toxic when mixed with sea water. This appears to support the idea that sea water itself may be slightly toxic. However, and thirdly, data for the spraying of sea water, without the addition of herbicide, indicate no such toxicity. Nevertheless further research on the toxicity of sea water is justified, because we did not evaluate the effect of adding the wetting agents, (present as part of the herbicide treatments), to either fresh or sea water.

It would be worthwhile extending the scope of such experiments to include the effect of penetrants, because the damage to bitou bush that follows storms could be due to enhanced foliar absorption of salt through abrasions caused by wind-blown sand. Alternatively, sand abrasion could facilitate entry of wound pathogens such as *Stemphylium* sp. (A. Nikandrow personal communication).

Aerial Spraying

Herbicide rates and selectivity By 1989, hand spraying indicated that winter applications of low doses of Roundup may selectively kill bitou bush. Consequently, we planned the first aerial application for winter 1989, choosing herbicide rates that straddle those used by hand. (Rates equivalent to 1:50 Roundup and 0.25 g Brush-off L^{-1} applied by hand at 400 L ha^{-1} are 4 L Roundup ha^{-1} and 100 g Brush-off ha^{-1}, respectively). Thus, the rates used in the trial were 3, 6 and 9 L Roundup ha^{-1} and 50, 100 and 150 g Brush-off ha^{-1}. All rates of both chemicals were toxic to bitou bush without causing measurable damage to coastal banksia, coastal teatree, coastal wattle, mat rush and coastal heath (Toth *et al.* 1993).

Independent of us, Anderson (1989) aerially applied 8 L Roundup ha^{-1}, at South Stradbroke Island, to control bitou bush growing either in the open or under a canopy of Casuarinas or scrub. Control was selective, with little damage to *Casuarina equisetifolia*, *Aegiceras corniculatum*, *Spinifex sericeus*, *Leptospermum laevigatum*, *Acacia longifolia* var. *sophorae*, *B. integrifolia*, *B. serrata*, *Imperata cylindrica*, *Alphitonia petriei*, *Archortophoenix cunninghamiana* or *Pandanus tectorius* var. *Australianus*; however, damage to *Macaranga tanarius* was substantial and fatal to *Stephania japonica* and *Carpobrotus glaucescens* (T. Anderson pers. comm.).

In 1991 we used 2 and 3 L Roundup ha^{-1} and 40 and 50 g Brush-off ha^{-1}. Again the lowest rates of both chemicals killed >95% of the bitou bush.

The effect of the lower rate of each herbicide was studied on seedlings of bitou bush, coastal teatree, coastal wattle and mat rush (Fullerton 1991). The key finding was that seedlings of the native plants were considerably less sensitive to the herbicides than were seedlings of bitou bush (Figures 1a and b). There was one notable exception: seedlings of coastal wattle that were young enough to be carrying leaves, rather than phyllodes, were just as susceptible to Roundup as bitou bush seedlings (Figure 1a). This was a surprise since mature coastal wattles are among the most herbicide tolerant of the native species tested (Table 3). There were two other important results. First, herbivory had a significant effect on two of the native plant species. Damage to mat rush was 35±5% (SE) and independent of herbicide treatment; however, damage to coastal wattle varied with treatment: 10% (control), 20% (Roundup) and 40% (Brush-off). Secondly, seedlings of bitou bush decreased in susceptibility to Brush-off as their size increased: eight weeks after spraying, seedlings that were exposed as new emergents, 0–14 cm tall and 15–30 cm tall, were exhibiting foliar damage of 90, 60 and 50%, respectively. These results raise the possibility of appreciable uptake of Brush-off through the roots. This should be explored.

Since 1992, 2 L Roundup ha^{-1} has been increasingly used in control programs, e.g. this winter 1100 ha was sprayed. During these treatments we and others have recorded the effects on 116 species of plants (Appendix I). Observations are continuing.

The rates of herbicide applied from the air to kill bitou bush (2 L Roundup, 40 g Brush-off ha^{-1}) are half the lowest rates that were successful when we used the LPG powered spray-gun (Table 2) and one eighth the rates applied when high volume spraying equipment is used (K. Hayes and I. Tye personal communication). Nonetheless, we have continued since 1992, to test reduced herbicide rates from the air. Treatments as low as 1 L Roundup and 20 g Brush-off ha^{-1} have occasionally given adequate control, indicating that there is some opportunity to further reduce herbicide inputs to the environment.

Spray volume From 1989–95 we varied the volume of water applied with the herbicides. The range for Roundup has been 0–60 L ha^{-1} and for Brush-off from 15–60 L ha^{-1}.

As the volume of mixture was decreased to 15 L ha^{-1}, the toxicity of Roundup increased, and of Brush-off decreased (Table 6). Retrospectively we learned that the latter effect is almost certainly due to the limited solubility of Brush-off (DuPont, undated).

Micronaires were used to apply <15 L of spray ha^{-1} and the results are dealt with in below.

Spray application using Micronaires

Micronaires enabled us to experiment with Roundup applied in ultra low volumes, e.g. mixed with 2 or 4 L of the Monsanto code numbered product MAL1024 or the neat CT Roundup formulation at 1–2 L ha^{-1}.

Results with MAL1024 were disappointing and CT Roundup was less effective than the same amount of chemical applied in 15 L of spray. Control was patchy probably due to drift. However, further research is warranted to reduce application costs.

Another reason for avoiding Micronaires is the possibility of damage to the canopies of trees. Roundup (2 L + 28 L water ha^{-1}) was sprayed above a canopy whose upper storey was dominated by blackbutt (*Eucalyptus pilularis*), to control bitou bush in the understorey. When the herbicide was applied using Micronaires, 30% of the leaves in the blackbutt crowns died. In contrast, there was no foliar damage, even at 3 L Roundup ha^{-1}, when the mixture was applied through spray nozzles. This difference reflects the relative proportions of the treatments that deposited on or passed through the tree canopy.

Table 6. Typical effects of spray volume on the toxicity of Roundup and Brush-off to bitou bush.

Herbicide treatment[A] Name	Rate	Spray volume (L ha^{-1})	Foliar desiccation[B] (%) 4 (months after application)	12
Roundup (v/v)	1	15	85	85
		30	80	80
		60	75	75
Brush-off (g ha^{-1})	30	15	25	40
		30	40	70
		60	60	80

[A] Herbicides applied from the air during winter.
[B] Each value is the mean of scores by two observers, on four plants per treatment, rounded to the nearest 5%.

Table 7. Effect of Pulse on herbicide toxicity to bitou bush.

Herbicide treatment[A] Name	Rate	Pulse[B] addition (Y/N)	Foliar desiccation four months after treatment[C] (%)
Roundup			
(L ha^{-1})	2	N	100
	1	Y	75
Brush-off			
(g ha^{-1})	20	N	509
	20	Y	90
	10	Y	40

[A] Herbicides applied from the air in 30 L spray during winter.
[B] 0.2% (v/v).
[C] Each value is the mean of scores by two observers, on four plants per treatment rounded to the nearest 5%.

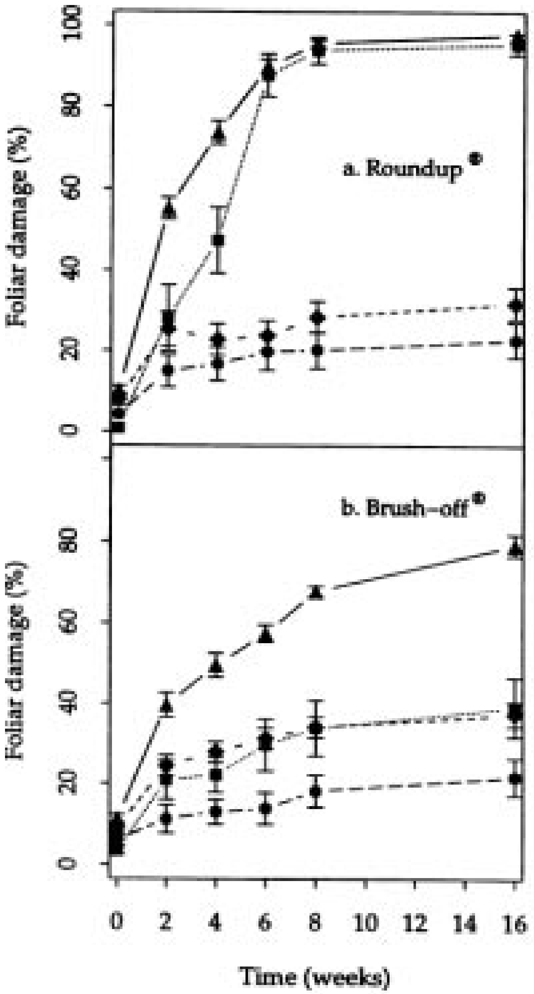

Figure 1. Foliar damage to seedlings of four plant spp. caused by (a) 2 L of Roundup ha^{-1} and (b) 40 g Brush-off ha^{-1}. Herbicides were applied in 30 L spray mixture ha^{-1}, from a helicopter during winter 1991 at Bherwerre Beach, Jervis Bay National Park. Species key: bitou bush (S), coastal wattle (■), *L. longifolia* (◆) and coastal teatree (●). The length of the bar through a point represents the value of the standard error.

Enhanced deposition on the tree canopy is more likely from the finer droplets produced by the Micronaires (average 100 µm in diameter) than the nozzles (average 300 µm diameter) (H. Combellack personal communication). By the time the spray reached the tree canopy, faster evaporation from the smaller droplets would have further increased the disparity between the average diameters of the droplets from the two sources.

Until the noted problems with drift and evaporation have been addressed, we do not recommend the use of Micronaires in the windy dune environment.

Additives Some of our 1989 Brush-off treatments did not include a wetting agent. From 1991 however, the wetting agent Ultrawet® was used at 0.1% (v/v) in accordance with recommendations by DuPont.

During hand-spraying, the addition of penetrants increased efficacy even in the presence of Ultrawet (Table 4); therefore we experimented with additions of Pulse (0.2% v/v) to mixtures sprayed from the air.

Pulse increased the efficacy of Brush-off by about 50% but the beneficial effect was much smaller with Roundup (Table 7), possibly due to the presence of wetting agent in the Roundup formulation and the low application volume.

Two mixtures of glyphosate and metsulfuron methyl became commercially available during 1995, viz., Trounce and Cut-out. Trounce contains 835 g glyphosate and 10 g of metsulfuron methyl kg^{-1}. Cut-out contains 63.2 g metsulfuron methyl and 760.5 g of glyphosate kg^{-1}. To compare these formulations with 2 L Roundup ha^{-1} and 30 g Brush-off ha^{-1}, respectively we used Trounce at 800 g ha^{-1} and Cut-out at 300 g ha^{-1}. Lower rates of both formulations were also applied, to explore whether the component herbicides were synergists, i.e. 600 g Trounce ha^{-1} and 200 g Cut-out ha^{-1}. The results indicate no synergism (data not shown).

Future The 1996 series of experiments will include the following treatments: Roundup Biactive®, a formulation with a wetting agent that is reputed to be less harmful to amphibians than the wetter used in Roundup; low herbicide rates; and, penetrants. Associated with the field trials is a most welcome, growing body of academic research addressing: the effects on birds and insects of removing Bitou Bush using aerial herbicide sprays; the fate of herbicides in the dune system; and, integration of biological and chemical control.

ACKNOWLEDGMENTS

The staff of Jervis Bay National Park, particularly Graeme Beech and Martin Fortescue, with Chris Nazer, ACT Parks and Conservation Service, gave us the first opportunity to trial herbicides against a range of native plants. Danny McNamara of the Hill 60 Restoration

Committee, Port Kembla; Stuart Thompson, BHP Newcastle; and David Stoupe, BHP Minerals, Hawks Nest facilitated the establishment of experimental sites for aerial spraying at Hill 60/Perkins Beach and Hawks Nest. We also thank: DuPont (Australia) Ltd., Monsanto Australia Ltd., and the NSW Environmental Trusts for financial and/or material assistance; and Harry Combellack and Zel Budolovic for technical advice.

Aerial spraying is a radical concept in the dune environment and without the support of the landholders and local communities it would have been impossible; consequently, we owe thanks to: Great Lakes Council, Karuah Land Council, NSW Land and Water Conservation, Wollongong City Council. We also thank members of special interest groups including: Herbert Beecham, Louise Brody, Sue Germon, Alan Lloyd, Marita Macrae, Hanns Pacy, Randle Pritchard, Gay Spies and Fay Sutton (conservationists); and Tein McDonald and Judith Rawling (bushland regeneration consultants).

REFERENCES

Anderson, T. (1989). Experiences with Bitou Bush in Queensland. Proceedings of the 5th Biennial Noxious Plants Conference, Volume 1, pp. 69-72.

Anon. (1992). *In* 'Kowari 2: Plant invasions – the incidence of environmental weeds in Australia', 188 pp. (Australian Nature Conservation Agency, Canberra.)

Davies, S.J. (1982). Bitou bush on the Bees Nest Range NSW. Undergraduate research report, Department of Geography, University of New England, Armidale, New South Wales

Fullerton, R.N. (1991). Chemical control of *Chrysanthemoides monilifera* (L.) T. Norl. (*Asteraceae*) and its effects on seedlings of selected native species. Honours Thesis, School of Biological Sciences, Macquarie University, Sydney.

Howden, S.M. (1984). The potential distribution of bitou bush in Australia. Proceedings of a Conference on *Chrysanthemoides monilifera*, NSW National Parks and Wildlife Service and NSW Department of Agriculture, Sydney, Australia, pp. 69-77.

Love, A. (1984). Distribution of bitou bush along the NSW coastal zone. Proceedings of a Conference on *Chrysanthemoides monilifera*, NSW National Parks and Wildlife Service and NSW Department of Agriculture, Sydney, Australia, pp. 53-64.

Love, A. and Dyason, R. (eds.) (1984). Proceedings of a Conference on *Chrysanthemoides monilifera*, 125 pp. NSW National Parks and Wildlife Service and NSW Department of Agriculture, Sydney, Australia.

Toth, J. (1989). Control of bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata* (L). T. Norl.) Proceedings 5th Noxious Plants Conference 1, 35-42.

Toth, J. and Smith, L. (1984). A low volume, gas-powered spray gun for application of herbicides to blackberry and other woody perennials. Proceedings of the 7th Australian Weeds Conference 1, 56-63.

Toth, J., Milham, P.J. and Maguire, M.J. (1991). Seasonal differences in glyphosate and metsulfuron methyl tolerance of bitou bush and four plant species indigenous to coastal NSW. Proceedings 6th NSW Noxious Plants Conference Volume 1, 18-20.

Toth, J., Milham, P.J. and Meszaros, I. (1993). Herbicide control of bitou bush. Proceedings of a National Workshop on *Chrysanthemoides monilifera*, ed. R.H. Holtkamp, pp. 39-42.

Toth, J., Milham, P.J. and Nazer, C. (1993). Aerially applied herbicides selectively control bitou bush growing in communities of indigenous plants on sand dunes. Proceedings 10th Australian and 14th Asian-Pacific Weeds Conference 2, 67-71.

Turner, D.J. (1985). Effects on glyphosate performance of formulation, additives and mixing with other herbicides. *In* 'The Herbicide Glyphosate', eds. E. Grossbard and D. Atkinson, pp. 221-40. (Butterworth and Co. Ltd., London).

Weiss, P.W. (1986). The biology of Australian weeds 14. *Chrysanthemoides monilifera* (L.) T. Norl. *Journal of the Australian Institute of Agricultural Science* 52, 127-34.

APPENDIX I
TOXICITY OF ROUNDUP TO NATIVE AND SOME INTRODUCED PLANTS[1]

Botanical name[B]	Observation[C] -observer[D]
Acacia implexa	NE -4
Acacia longifolia var. *sophorae*	NE -1,2,4
*Acacia saligna**	NE -4
Acacia suaveolens	SD -4
Acacia terminalis	NE -4
Acacia ulicifolia	NE -2,4
Actinotus helianthi	NE -2,4
Aegiceras corniculatum	NE -3
Allocasuarina distyla	NE -2
Allocasuarina littoralis	NE -2
Alphitonia excelsa	NE -3
*Ammophila arenaria**	NE -4
Aotus ericoides	NE -2
Astroloma pinifolium	NE -2
Austromyrtus dulcis	NE -3
Avicennia marina	NE -3
Banksia integrifolia	NE -1,4
Banksia serrata	NE -2,4
Billardiera scandens	NE -2,4
Blechnum sp.	NE -3
Bossiaea ensata	NE -2
Bossiaea heterophylla	NE -2,4
Brachyloma daphnoides	NE -4
Breynia oblongifolia	NE -2,4
*Briza maxima**	NE -2

Botanical name[B]	Observation[C] -observer[D]
Cakile maritima ssp. *maritima**	NE -4
Canavalia rosea	NE -3
Carpobrotus glaucescens	NE -2 SD -1,4,5
Cassytha pubescens	NE -2,4
Casuarina glauca	NE -2
Clematis glycinoides	NE -4
Comesperma ericinum	NE -2
Commelina cyanea	NE -2,4
Conospermum taxifolium	NE -2
Correa alba	NE -2
Corymbia gummifera	NE -4
Cupaniopsis anacardioides	NE -3
Dianella caerulea	NE -2
Dianella revoluta	NE -2,4
Dillwynia glaberrima	NE -2
Dodonaea triquetra	NE -1,4
Duboisia myoporoides	NE -4
Einadia hastata	NE -4
Elaeocarpus reticulatus	NE -4
Empodisma minus	NE -3
Eucalyptus botryoides	NE -4
Eucalyptus pilularis	NE -2,4
Eucalyptus punctata	NE -4
Eucalyptus robusta	NE -4
Eucalyptus signata	NE -2
Eustrephus latifolius	NE -3
Excoecaria agallocha	NE -3
Gahnia clarkei	NE -3,4
Gleichenia dicarpa	NE -3
Glycine clandestina	SL -4
Gonocarpus teucrioides	NE -2
Hardenbergia violacea	NE -2 SD -4
Hibbertia fasciculata	NE -2
Hibbertia linearis	NE -2
Hibbertia obtusifolia	NE -2,4
Hibbertia scandens	NE -2,5
Hibbertia vestita	NE -3
Homoranthus virgatus	NE -3
Hydrocotyle bonariensis	NE -1,2,4
Imperata cylindrica var. *major*	NE -2,4,5
Indigofera australis	NE -4
Ipomea pes-caprae ssp *brasiliensis*	NE -3
Isolepis nodosa	NE -2
Jacksonia scoparia	NE -2
Kennedia rubicunda	NE -1,2 SD -4
*Lantana camara**	SL-4
Leptospermum laevigatum	NE -1,2,4
Leptospermum liversidgei	NE -2
Leucopogon ericoides	NE -2
Leucopogon parviflorus	NE -1,2
Leucopogon virgatus	NE -2

Botanical name[B]	Observation[C] -observer[D]
Lomandra longifolia	NE -1,4
Lomandra multiflora	NE -2
*Lupinus cosentinii**	NE -4
Marsdenia rostrata	NE -4
Melaleuca armillaris	NE -4
Melaleuca ericifolia	NE -4
Melastoma affine	NE -3
Monotoca elliptica	NE -1,2,4
Monotoca scoparia	NE -2
Myoporum boninense	NE -2
Myoporum insulare	NE -2
Pandorea pandorana	NE -2
Parsonsia straminia	NE -3
Persoonia lanceolata	NE -2,4,5
Persoonia linearis	NE -4
Phebalium squameum	NE -2
Pimelia linifolia	NE -3 SD -4
Pittosporum revolutum	NE -4
Pittosporum undulatum	NE -2
Platysace lanceolata	NE -2
Pomaderris discolor	NE -2
Pteridium esculentum	NE -2,4,5
Ricinocarpos pinifolius	NE -2,4
Scaevola calendulacea	NE -2 SD -5
Schoenus ericetorum	NE -2
Sesuvium portulacastrum	NE -3
Smilax australis	NE -3
Smilax glyciphylla	NE -4
Solanum vescum	NE -4
Spinifex sericeus	NE -2,4
Stackhousia spathulata	NE -2
Stephania japonica	NE -3
Stylidium graminifolium	NE -2
Styphelia viridis ssp. *viridis*	NE -2
Syzygium oleosum	NE -3
Themeda australis	NE -1,4
Trachymene anisocarpa	NE -4
Westringia fruticosa	NE -2
Zoysia macrantha	NE -3

[A] A compilation of results from 1989-1995 for the spraying of 2 L of Roundup in 30 L water ha^{-1} from a helicopter, during winter (1 May–31 August).

[B] * indicates an introduced species.

[C] Key to observations: NE = no effect; SL <10% foliage burn; M ~25% foliage burn; SD = <20% dead.

[D] Key to observers: 1 Toth, J., Milham, P.J. and Nazer, C. at Jervis Bay; 2 Whelan, R.J. and Kohler, G. at Hill 60 Port Kembla and Hawks Nest; 3 Watson, G.W. near Yamba; 4 Gosper, C. at Perkins Beach; 5 Schroder, M. and Thomas, J. at Myall Lake and Angourie.