ASSESSMENT OF THE OUTCOMES OF WEED MANAGEMENT TECHNOLOGY IN URBAN AREAS – OVERVIEW

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Summary Weed control in urban open space is currently at a critical phase. While there is pressure to reduce costs in landscape management in general, the technological advantages developed by the use of herbicides in weed control management have increasingly come under scrutiny for widespread use in urban public open space management. The negative public perception of herbicide usage coupled with the lack of a consistent technical understanding of the range of herbicide products and their applications within public open space has essentially limited widespread use of herbicides with glyphosate being the single most widely used product in non turf areas.

Landscapes within public open space essentially differ from commercial production plantings by possessing both hard and soft elements that are often non uniform in nature. The transference of weed control technologies formed on the more regular environment of commercial production into public open space has lessened their viability rather than fulfilled their noted potential.

The alternatives to herbicide use, which have been variously implemented, include mulching, plant selection and planting design and a range of other pre- and post-planting systems such as lowering the soil nutrient status, steam and flame thrower techniques and physical removal. These have had inconsistent success as stand alone approaches but work more effectively in combination with glyphosate use, especially at pre-planting rather than at the post-planting long term management phase. Given the restrained use of herbicides in public open space management, a greater emphasis is required on the development of planting structures and plant selection to solve weed management dilemmas.

INTRODUCTION

Weed control in urban open space management forms a major component of the maintenance program. Within urban public open space, however, there is a wide range of conditions where weed control is required. Landscape profiles can range from those containing highly contrived annual bedding schemes, where weeds are mostly controlled by intensive physical removal, to semi natural and natural bushland. This mix of landscape types, and styles and their various components, has made the transference of standard weed control strategies from the more uniform environment of commercial crop production, difficult to implement (May 1991). Weed control strategies have therefore been more limited by comparison with commercial crop production and have necessarily needed to form compromises with recommended optimal application procedures.

The responsibility for developing weed control strategies has mostly been seen as a task undertaken almost solely by grounds maintenance staff rather than actively engaging the range of disciplines involved in the planning and management of urban open space. Management agencies generally only articulate overall expectations in standards derived mostly from public opinion. Solutions drawn from the initial design phase through to implementation and subsequent management, however, are required to form unique approaches to weed control to both better suit the urban environment and to meet ever increasing cost pressures while at the same time delivering quality landscapes.

NATURE OF URBAN OPEN SPACE LANDSCAPES

The range of features which differ from commercial plantings in public open space can be broadly divided into a number of areas. May (1991) provides a convenient approach to discussing the nature of the urban weed environment by categorizing these under four main headings: planting geometry, taxonomic diversity, nature of the management authority and geographic location. These have been used under the following general divisions as a basis to describe some of the important features of the weed environment in urban landscapes which have effected the implementation of weed technologies.

Vegetation types and styles Except for the formal annual bedding schemes mentioned previously the vast majority of planting throughout public open space is non-linear in nature. This renders equipment such as boom sprayers for herbicide application impossible (May 1991) and physical removal has therefore been much used to control weeds in urban landscapes.

The range of taxa in any one planting scheme in urban landscapes is often large over a short distance. Responses to any single control method, especially the use of herbicide applications, may be complex and vary from scheme to scheme. Plant diversity in any one scheme can be extreme, from a highly diverse collection of plants

which make up the 19th century shrubbery, still a fashionable planting style in public open space whether Australian natives or exotic plants are used, to the less diverse, but still varied, bushland style of planting where use is made of a suite of indigenous plants. Greater use of less diverse and more uniform plantings have been made over recent times in the form of ground covers and shrub massing, but these have often not been well implemented and have not, in many cases, fulfilled their initial aims. In the context of weed management these plantings still offer considerable ability in the long term management of a range of landscapes within the urban environment (see below for further discussion of this form of planting).

Management policies and objectives In general the policies and objectives set by the range of agencies concerned with urban open space management are aimed at weed suppression using as wide a range of techniques that will be compatible with resource availability and public expectations.

The response, however, in dealing with the range of inputs into public open space management, especially those formed from community expectations and opinion, has been various depending on the agency responsible. These have been particularly evident in community concerns to the use of herbicides which have ranged from a complete ban on herbicides to the use of glyphosate only.

Total bans on herbicides in urban areas have occurred in some overseas cities, especially in Germany where herbicides are banned in urban areas although some are still permitted for widespread use in commercial production (Hitchmough 1995). Locally the misuse of herbicides, has at least in the past, contributed to the implementation of herbicide bans. A local Melbourne metropolitan council totally banned herbicides for a number of years as a result of the misapplication of a residual herbicide by one of its contractors which killed a row of trees and severely affected plantings in nearby residential gardens of one of its premier urban streetscapes (P. Osmond personal communication 1996). The reintroduction of herbicides to the area was limited to glyphosate which occurred as a response to community concerns over the increase of weeds throughout the municipality. Alternative weed control measures introduced, mainly physical methods, were not able to be sufficiently resourced to suppress significant weed growth (Lindsay 1989).

Weed control in areas of high population densities Landscapes in urban areas coincide with high public density and any weed control strategies need to be developed to satisfy the scrutiny of public opinion, both in the processes of control and in their outcomes. As discussed previously, herbicide use has especially been criticized, however, this has not only come from an increasingly environmentally conscious public but also from many professionals and operators in the field. Health and safety programs and policies have contributed strongly to concern over chemical use in the workplace and procedures which include roping off areas and the wearing of safety suits have also further alerted the public to the issue. These have also added considerably to increased costs and the difficulties in administering and implementing spraying programs. Brereton (1992) in a discussion of herbicide usage in public urban space states that "It is too much to expect that small horticultural establishments be they councils or park management should possess the expertise associated with, not only, herbicide selection and application but also a capacity to deal with issues such as; diverse storage problems, shelf life, safety training, chemical spill training, building and equipment maintenance, amongst some of the associated responsibilities when using herbicides."

Apart from the use of chemicals in high density areas, public attention is also directed at standards in visual appearance. There is an expectation that areas within urban open space will be managed to be free of weeds, however, this is mostly born from a 'neat and tidy' approach to the landscape rather than an extensive knowledge of the weed flora and an ability to identify a wide range of individual weeds in a given landscape. Programs developed to inform the public are needed to improve public understanding of the nature and extent of the weed problem. The excellent 'Live Local Plant Local' guide and poster developed by the Shire of Nillumbik in Melbourne (Crago 1996), provides a good model for educating residents about their indigenous flora. Information about weeds packaged in a similar way would assist in better informing residents about significant weed issues.

WHAT IS THE NATURE AND EXTENT OF THE URBAN WEED PROBLEM

In a recent survey of native bushland in major Australian cities weed infestation was found to be a significant management problem. The average level recorded by all respondents for weed affected bushland was 60% with Melbourne reporting the highest at 90% (Table 1) (Dignam 1996).

The report states that weed pressure was by far the main problem in bushland re-establishment (92% of respondents) and that herbicides, in particular glyphosate, were vital to native vegetation management (Table 2). The range of non-chemical methods recorded by respondents included slashing, burning, manual weeding, mechanical clearance, biological control and hot/water

steam treatment. Manual weeding was the preferred method (Dignam 1996).

The report also records that 80% of respondents did not have the resources to properly control weeds (Dignam 1996).

While this survey reports on the extent of the weed problem in urban bushland areas the concerns over weed infestation pressures and management resource problems in areas with different landscape profiles would be expected to be similarly recorded, although the dominant problem weed species may alter.

The impact of weeds in urban landscapes has been well documented and generalized under the following: competition for resources, importation and carriers of pest and diseases and aesthetic/visual detraction (Hitchmough 1994). However, by re-evaluating the aims and objectives of the particular landscape profile being managed, these values could be significantly altered. Acceptance of some weed species in certain landscapes is further discussed below, however, this may allow a better priority system of resources to be directed to places of greater value in terms of weed control management.

Table 1. Percentage of bushland affected by weeds in major Australian cities. (Table adapted from Dignam 1996).

City	Bushland affected (%)[A]	Bushland over-run (%)[A]
Sydney	50	25
Melbourne	90	50
Brisbane	50	40
Adelaide	40	7
Perth	70	50

[A] recorded by all respondents.

Table 2. Range of herbicides used by respondents as the main herbicide product in urban bushland management. (Table adapted from Dignam 1996).

Herbicides	Used as main herbicide product (%)
Glyphosate	72
Brushoff	4
Grazon	4
Frenoc	4
Trounce	2
2,4-D	4
Fusilade	4
None in particular	6

THE RANGE OF OPTIONS FOR THE CONTROL OF WEEDS IN URBAN OPEN SPACE

The development of an integrated approach to weed control management is seen as an important goal to achieving lower costs in urban landscape management (May 1991, ACT Parks and Gardens Service 1994). While a combination of approaches is required, weed control can be conveniently discussed under several well defined areas.

Physical removal The physical removal of weeds is still traditionally practised in urban open space. It is mostly restricted to the removal of weeds from established vegetation in smaller isolated profiles rather than broad sweeps of landscape, where the time consuming nature of this method of control prohibits it use. Its effectiveness is limited mainly to plants which do not have a strong ability to perenniate by possessing a specialized biology such as rhizomes or stolons and must be followed by mulching to prevent weed seed germination in soil disturbed as a result of removal.

The use of mechanical tillage by hoeing, widely practised in the past, is little carried out currently in urban open space. Apart from being too labour intensive this method also caused considerable damage to the roots of existing vegetation, exposed the weed seed bank with a resultant increase in weed seed germination and spread perennial weeds to further exacerbate the weed problem. Mechanical tillage is still widely practised in the removal of vegetation for the preparation of new areas but as discussed above must be followed by other control methods to be successful. The identification of the vegetation to be removed is also important as it could lead to the spreading of perennial plants. This problem still occurs regularly in the establishment of new landscapes where mechanical digging and cultivation are practised.

The use of thermal techniques for weed control have only been used to a limited extent in urban weed control. Spirit and gas fired flame guns have been traditionally used, especially for the control of weeds in paved surfaces, however more recently hot water used in the 'Wipuna' system of weed control has been trialled as an alternative to herbicide treatments (K. James personal communication 1996). This system is more costly by comparison to herbicide treatments but offers an alternative to chemical use and therefore maybe useful for areas with high public use. Long term control over perennial weeds using this system is still being assessed (P. Osmond personal communication 1996). The use of fire has been successfully used in some bushland sites for annual weed suppression, however, this has been limited to areas of low human population densities and is therefore not a realistic option for widespread use in urban landscapes (Hitchmough 1994).

Herbicides The use of a wide range of species and planting patterns in urban open space along with negative public perceptions, as already discussed, has restricted the number of herbicide types used in urban open space. Residual herbicides such as simazine, dichlobenil and oxadiazon while showing a great deal of potential for use in public open space for longer term weed control have not been extensively used. Apart from the fact that both the public and horticultural practitioners generally view them as being among the most environmentally unfriendly, their application is also not well understood in urban open space horticultural management (Robinson 1987). The use of contact herbicides, for the control of annual weeds, has also become limited in public open space, especially with the toxicity of herbicides such as paraquat and diquat. The lower toxicity glufosinate ammonium in the form of Basta™ however has more recently gained a place for the control of annual weeds, particularly in bushland sites where spot treatments are used.

Table 3. Response of a range of landscape plants to overspraying with glyphosate from separate trials undertaken in summer and autumn. (Table adapted from Cockerell 1991, Verspay 1991).

Species/ cultivar	Optimal dosage rate[A] for least injury (kg a.i. ha^{-1}) Summer	Optimal dosage rate[B] for least injury (kg a.i. ha^{-1}) Autumn
Juniperus sabina	2.0	4.4
Correa 'Dusky Bells'	sensitive[C]	4.4
Leptospermum juniperinum 'Horizontalis'	*	4.4
Hardenbergia violacea 'Happy Wanderer'	*	2.2
Myoporum parvifolium	*	2.2
Rhagodia spinescens	*	sensitive[C]
Grevillea biternata	*	sensitive[C]
Agapanthus praecox subsp. *orientalis*	3.0	*
Coprosma acerosa	1.0	*
Grevillea 'Bronze Rambler'	1.0	*
Grevillea 'Poorinda Royal Mantle'	2.0	*
Juniperus conferta	2.0	*
Juniperus horizontalis 'Glauca'	2.0	*

[A] dosage rates applied in trial-1.0, 2.0, 3.0 kg a.i. ha^{-1}.
[B] dosage rates applied in trial-2.2, 4.4 kg a.i. ha^{-1}.
[C] sensitive to all dosage rates applied.
* no results recorded for species/cultivar.

As already mentioned previously and shown in Table 1, the translocated herbicide glyphosate is by far the main herbicide used in public open space and although this table represents its use in urban bush land management this also applies to the complete range of landscape profiles. Glyphosate as used in the products Zero™ and Roundup™ is also well understood and widely used in the domestic garden and therefore has a wider public acceptance, at the present time, than other herbicides. The fact that it can also be applied to a wide range of plant types because of its translocation ability further reinforces its use in urban environments by lending itself to a convenient singular prescriptive method able to be used in a diverse range of landscapes.

The use of glyphosate is now such that the management of weeds in urban areas has become dependent on it for setting standards within current resourcing levels, staffing structures and weed control contracts. Over reliance on its use for weed control can be seen in many urban planting schemes which either by poor vegetation management or initial design are not inherently successful at suppressing weeds. Rather than attend to new or revised planting to achieve better weed control glyphosate, often in combination with mulch, is used on a continual and repeated basis to meet weed control standards. The over reliance on glyphosate may also cause a proliferation of weeds which are difficult to control with this chemical such as *Nothoscordum gracile*, *Salpichroa origanifolia*, *Allium triquetrum* and *Tradescantia fluminensis*.

An area requiring more investigation is the possible over spraying of desirable vegetation with herbicides to eradicate weed infestations. Groves (1991) suggests that many Australian plants may have greater resistance to herbicides than introduced weeds but that this may be dose related. Trials undertaken by (Verspay 1991) and (Cockerell 1991) (Table 3) using glyphosate on a range of both native and exotic landscape plants indicate that both dose and season of application are important.

Mulch The use of mulch has been one of the most outstanding successes in the control of weeds in Australian landscapes over the past 20 years. A wide range of mulches have been used and can be conveniently divided into organic mulches; such as the various wood and bark chips, pea straw, mushroom compost, leaf mould etc. and inorganic mulches such as gravel and the polypropylene sheet type mulches in various weed mat products. The latter provides excellent weed control but is criticized for its visual intrusion in planting schemes because of its

'unnatural' appearance as has the use of old carpet as sheet mulch in bush regeneration schemes. This is sometimes overcome by overlaying with a bark or woodchip mulch to improve its appearance but this increases implementation costs and can allow weed invasion over the top in the organic layer (Derr and Appleton 1989). There is a need for more research on the ability of various different mulch types to control weeds as shown by initial trials on wool used as mulch. This trial showed good control of broad leaved weeds but poor control of narrow leaved grass weeds (Pinnuck 1994)

In public open space management both wood and bark chips are by far the most used mulch material across the complete range of landscape profiles. These have not only been popular for their visual appearance but also their ease in availability from tree and garden recycling centres. The coarser chip types, with greater air spaces between them, have superior weed control effects than finer graded mulches (Billeaud and Zajicek 1989), however, if placed at a greater depth than 75 mm may reduce oxygen and water infiltration to the soil profile and, subsequently, cause detrimental effects to plant growth.

The broadscale acceptance of the use of mulch in urban landscapes has been such that it has tended to replace appropriate planting in many schemes. For example, the higher planting densities required for the successful establishment of groundcovers, are often reduced and replaced by a cover of mulch. Plant replacement required in degraded vegetation is also often merely new mulch rather than new plants. While mulch used in this way will provide some short term weed control, invasion inevitably occurs on breakdown and control relies then on continual replacement and herbicide treatment as discussed previously. This often doesn't occur until weed invasion has already taken place.

Biological control Biological control has not been utilized extensively in urban landscapes to date. While it is an attractive option the level of control at present is not adequate. Hitchmough (1994) states that 'it is currently restricted in landscape management because of the limited range of control organisms available, and the lack of funds and expertise available to establish and manage programs in practice—in the longer term, it seems inevitable that biological control will become more widely used'.

Planting The use of planting is perhaps the most important consideration in obtaining both short and long term weed control. As May (1991) succinctly states 'This will reduce the niches available for weed invasion'. It could be argued that the best form of weed control is through competition with desirable plant species. Despite this, however, planting for weed control continues to be an area which is still not well understood by both designers and landscape managers.

Planning for planting In general, a holistic, planned approach, is required to establish the appropriate balance of vegetation profiles to achieve the most effective and efficient weed control outcomes. For example the use of highly ornamental planting schemes containing plants which have very little sustained weed control ability, such as annual bedding, traditional rose beds and other high diversity ornamental plantings should be limited in number and extent to locations where they will have the most effect (i.e. a traditional park can have small beds placed at the entrance where the impact will be greatest but not in the centre or other lower use areas where cost effectiveness will be greatly reduced). The use of these types of ornamental plantings in roundabouts and road verges needs to be similarly planned. All too often the extent in area developed using these styles of planting far exceeds those needed to create the desired impact. The resultant landscapes, which require good weed control as part of their visual attraction, are usually either weed invaded or alternatively absorb a disproportionate component of the maintenance input to the detriment of other areas.

Planning is also important in the design of areas to establish appropriate locations for vegetation. Areas set aside for vegetation are often too restricted in area, often with high edge to area ratios, to establish and maintain quality plantings. A good example here is the narrow beds often associated with car parks and other commercial spaces. These beds normally suffer extreme pressure from both cars and pedestrians to the extent that vegetation regularly fails and weed invasion occurs. It would be preferable to rationalize these spaces and combine areas to form larger zones for easier establishment and management of vegetation.

Planting design and plant selection A combination of both design and plant selection is required to achieve long term weed control in urban open space. Two very different styles of planting currently used in public open space potentially lend themselves to lower management inputs with respect to weed control. The use of ground cover and shrub massing which has been much used for freeway embankment planting and other smaller roadside verge plantings and the nature like landscapes which have been reconstructed especially along stream corridors, transport corridors and on the urban fringe could have a significant effect on the efficiency of weed control in urban areas if properly planned.

Ground cover and shrub massing One of the main objectives in using ground cover and shrub massing in planting design is to form a dominant vegetation cover of desirable plants to achieve long term weed control (Thoday 1982). A dominant cover is established by selecting plants which posses some or all of the following characteristics:

- are able to knit together to form a complete and stable cover across the ground for at least 8–10 yrs. This time length is required to compete in cost effectiveness with mown turf as an alternative landscape treatment.
- good canopy density to effectively exclude light from the soil surface
- a reasonable height (or depth), at least 20 cm, to exclude light from the soil surface. Plants lower than this are rarely able to form a complete cover without significant gaps for weed invasion.
- sufficient continual leaf drop to form a layer of mulch on the ground
- allelopathic effects which inhibit weed growth

(Thoday 1982, Hitchmough 1994)

– this last attribute is not well understood and more information is required not only for ground cover plants but particularly species for planting where no understory is required.

While as stated above plants need to form a closed canopy for at least 8–10 years, a shorter time may be possible if canopy renewal can be easily achieved through severe pruning techniques (Looker 1992). Unless a plant is able to form a stable canopy for an extended period, such as some of the conifers used for ground cover (e.g. *Juniperus sabina*) then the ability to recover an aesthetic-functional form via severe pruning should be a key selection criterion.

There has been a great deal of disappointment in the effective use of ground cover and shrub massing to form a dominant cover. Apart from the lack of attention to the selection of plants with the above characteristics the issue of plant spacing has been poorly understood by designers and managers alike to achieve the desired goals. Plants are often placed too far apart to finally form a complete cover and if they do eventually come together substantial weed invasion may already have taken place. While planting trials have not explored this issue very widely in Environmental Horticulture research, plants, if selected from uniform stock, should be considered at closer spacings than those traditionally given. Thoday (1982) suggests that dominant ground cover plantings may be created in this way by nurture rather than by relying merely on those plants which have the biological ability to spread. Good examples of the effectiveness of shrub massing in long term weed control can be seen on some of the early freeway embankment plantings in Melbourne where a continuous and dominant cover has been maintained for at least 15 years with little or no management inputs beyond establishment.

Nature-like landscapes The use of naturalistic plantings and bush regeneration has been a strong emphasis in many local authority plantings over the past ten years. These landscapes have not only been developed using indigenous species for conservation purposes but also used to recreate a local identity, as well as the belief that ultimately they will deliver a lower maintenance landscape. The results of this last statement, however, will rely to a large extent, on whether issues such as weed control inputs can be significantly reduced over other landscape profiles. Hitchmough (1995) in a discussion of the total ban of herbicide use in managing greenspace states that "The most cogent argument to the contrary (that is the total banning of herbicides) is ironically likely to come from conservation groups involved in the management (elimination?) of 'environmental weeds' in remnant native vegetation". He further proposes the following range of options for the development and management of these landscapes without the use of herbicides:

- Use of low fertility sub soils and gravels which are substantially weed free to establish native plantings.
- Develop naturalistic planting styles which when invaded by weedy species do not appear to be visually intrusive because of the diverse but repetitive nature of the landscape.
- Planting strong growing undercanopy species such as *Lomandra*, *Gahnia* and *Dianella* in large drifts to reduce niches for weeds.

(Hitchmough 1995)

Among these options Hitchmough (1995) accepts the inevitable invasion of weeds, at least to some extent, a point which may be unpalatable to purists in the field. The weed invaded bushland area attached to Kings Park Botanic Gardens in Western Australia provides a good example of public perception to weed invaded natural areas. The area is substantially invaded with *Watsonia* and *Freesia* species which attract substantial positive appeal from visitors because of the strong element of colour they provide throughout the ground layer at certain times of the year. Despite this however the gardens have a legitimate policy to eradicate these weeds as part of the conservation of the site and its interpretation of the indigenous flora of the area (S. Forbes personal communication 1996). Fox (1991) supports this approach by suggesting that mixes of exotic and native species may need to be accepted in urban areas but that in designated conservation zones alien plants should be completely eradicated.

In the development of naturalistic plantings the acceptance of weed invasion, at least in the short term until the landscape becomes further established and able to suppress weed species, may well be a more acceptable option. Another option not often explored is a phased approach of planting quick growing native species which can compete with weeds to obtain initial weed control (Groves 1991) until the final desired vegetation is reached rather than merely planting the expected final mix at the beginning. *Goodenia ovata*, a quick growing but relatively short lived indigenous plant to the Melbourne region, for example, initially forms a dense canopy and hence has a good ability to shade out weeds in the short term until other vegetation becomes established. Some of the faster growing acacias may also be used for this purpose (Groves 1991). This concept could also be extended to other landscape profiles where slower growing species are used.

CONCLUSION

The diverse nature of urban landscapes and their location in densely populated areas often make weed control strategies difficult to implement. Strategies developed for agricultural use have necessarily needed to be tempered, modified and combined to form a more integrated approach to form acceptable weed control standards in urban open space.

The dependence on both mulch and the use of glyphosate has been over emphasised in the management of urban environments and requires balancing with a greater focus on planting schemes to form more sustainable strategies for weed control. At present there is a considerable lack of understanding and skill in both the design; selection of appropriate plants and maintenance of areas to achieve quality plantings able to suppress weeds to better meet these goals.

While there is a large number of practitioners involved in the control of weeds in urban open space it has not attracted a strong research interest in developing unique solutions. More information is required on the identification of weeds and their associated ecology in specific urban areas (Brereton 1993) to better establish management programs. In addition resources need to be allocated both for further research into specific weed problems and the development of education programs targeted to the general public.

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