Department of Agriculture
Government of Western Australia

Declared Plant Control HANDBOOK

Sixth Edition 2002

Recommendations for the control of Declared Plants in Western Australia

Reviewed October 2005

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Contents

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1 Introduction to declared weed control

Plants may be "declared" by the Agriculture Protection Board under the *Agriculture and Related Resources Protection Act 1976*. If a plant is declared, all landholders are obliged to control that plant on their properties. Declarations specifies a category, or categories, for each plant according to the control strategies or objectives which the Agriculture Protection Board believes are appropriate in a particular place.

Among the factors considered in categorising declared plants are:

- the impact of the plant on individuals, agricultural production and the community in general,
- whether it is already established in the area, and
- the feasibility and cost of possible control measures.

Declared plants are gazetted under five categories, which define the action required. The category may apply to the whole of the State, districts, individual properties or even paddocks.

The five categories are:

P1 Prevention
Plants which can not be introduced or spread. Most declared plants fall under this category.

P2 Eradication
Includes potentially serious weeds, which are not yet widely established.

P3 Control
Plant infestations should be reduced over time if eradication is not realistic.

P4 Containment
Plants should be prevented from further spread. Includes plants that are so well established that reducing the areas of infestation is not practical or economical. Also includes plants that can not be controlled with existing technology.

P5 Special action on public land
This provides for control on land under the control of local Government, saleyards and roadsides.

A current list of declared plants can be found at the departmental web site (http://www.agric.wa.gov.au).

2 Methods of weed control

Land managers have several options for controlling most weeds, of which herbicides are only one. In many cases an appropriate mix of control methods will be most effective. The combination of more than one control method is known as integrated weed management (IWM). Any combination of the methods described below would constitute an IWM program.

2.1 Cultural control

Grubbing and cultivation can be used to control many weeds that are present as isolated plants or in small patches. Perennials that do not have an extensive root system can also be removed in this way. However some weeds, such as silverleaf nightshade and skeleton weed, are spread by cultivation, due to the ability of cut pieces of root to regenerate, as well as regeneration of plants from below the cultivation depth.

Mowing and slashing are effective ways of controlling many annual thistles, but the timing of the operation is important. It is best carried out between the budding stage and first flowers. If done earlier than this, there is a risk that the severed stem will produce a new flowering shoot. If carried out later than early flowering, the cut portions of the plant may contain enough moisture for some of the immature seeds to reach maturity and become fully viable.

Burning on its own is of limited use in controlling weeds. However, it is a useful preliminary operation in the control of cape tulip. Burning destroys the surface trash and allows the maximum amount of water to penetrate the soil early in the season when ground temperatures are still warm, which stimulates a high proportion of cormils to sprout. Burning is also useful in destroying the dead canes in blackberry stands, thus thinning out the stand and making it easier to spray effectively in the following season. Burning mature bushes that have been grubbed encourages dormant seeds to germinate. If the resulting seedlings are destroyed by other methods this will reduce the time required to eradicate the weed.

Grazing can destroy weeds or reduce their capacity to produce seeds. Sheep especially will seek out and eat seedlings when there is no other green feed available. They are particularly effective in destroying paddock infestations of kochia and gorteria. Paterson's curse can also be effectively controlled by heavy grazing; in fact, many badly infested farms are a result of poor pasture utilisation. Goats are particularly effective in grazing woody plants and also removing flowering heads from thistles.

Spray-grazing and spray-topping are weed control techniques that exploit the weed-killing potential of large numbers of stock grazing an infested pasture previously sprayed with a sub-lethal quantity of certain herbicides. Weeds sprayed with a phenoxy herbicide appear to become more palatable. Full details of spray-grazing technique are given in section 2.3.1 and spray-topping in section 2.3.2.

Competition between plants is important in the control of seedlings. In Western Australia pasture competition is mainly important in the control of winter-growing weeds because most of our pastures are based on winter-growing annuals. The "spray-graze" technique also makes use of this competition. Seedlings of doublegees, Bathurst burr and skeleton weed are very sensitive to competition from other plant species.

2.2 Biological control

Biological control is the use of natural predators and diseases as agents to attack weeds and other pests. Biological control agents are usually insects, but fungi, bacteria and nematodes (eelworms) are sometimes used.

Potential biological control agents are found by examining the weed in its area of origin and looking for damage caused by natural enemies of the weed. These are usually organisms that have evolved along with the weed, but for some reason did not spread with it to new habitats in Australia.

Once possible biological control agents have been identified, they are tested overseas to ensure that they are host-specific, ie they will not attack any plant other than the weed to be controlled and therefore will not become a pest if introduced to Australia. Native and cultivated plants related to the weed are exposed to the biological control agent to see if they too are attacked. Other plants not related to the weed, especially those that it would not have encountered in its home range, are also tested.

Many insects will starve rather than attack another plant. Some agents are so specific that they will attack only one variety of a plant species. For example, the rust fungus *Puccinia chondrillina* will only attack the narrow leaf form of skeleton weed, leaving the intermediate and broad-leaved forms untouched. Others have a limited range of possible hosts. If the agent appears to be specific to its host, it is usually brought to Australia for further testing in quarantine. Final approval for release of the agent depends on further host specificity tests confirming that the agent is indeed host specific. Before release, the agent is bred under laboratory conditions to make sure that it is free of disease organisms, parasites or predators that might attack it.

Biological control has certain unique advantages:

- Once the cost of testing and introducing control agents has been met, the on-going costs are small.
- In most cases, there is no need to find and identify every individual weed to be treated. An effective agent will search out all suitable plants of the weed.
- Biological control has no adverse affect on human health or the environment.
- Biological control is self-sustaining. Once the initial research work has been completed and the biological control agents released, little or no further money is required.
- Unlike certain herbicides, development of host resistance is not normally a problem.

- Biological control is compatible with most other control techniques (except sometimes the use of insecticides and herbicides).
- Biological control reduces the vigour, competitiveness and reproductive capacity of the weed, making it more manageable.

On the other hand there are some disadvantages:

- Biological control agents are expensive to find. The greatest expense is during the field survey and early testing stage which must be conducted overseas.
- Suitable agents may not even exist.
- Potential agents are also expensive to test for specificity. Host specificity testing may take several years to complete because of the need for thoroughness (however, herbicides often take as long and cost even more to develop).
- Biological control can never eradicate a pest organism completely, because if the control agent reduces the pest population too far, it destroys its own food source.
- Biological control operates over large areas. Therefore it cannot be limited to individual properties or paddocks.

2.3 Chemical control

Chemicals are used extensively to control weeds. There are many herbicide types and an even greater number of products available. Herbicides give operators a degree of flexibility in control of the weed that is not available using other methods. Operators can vary the timing and size of the operation and, in most cases, the cost is reasonably low.

Always read the label to ensure the herbicide is registered for the weed and situation you intend to use it for.

In many cases control of a weed is best effected by a combination of strategies which together have a maximum impact on an infestation.

2.3.1 Spray-grazing

"Spray-grazing" is a method of controlling declared plants in pastures. It makes use of the fact that a sub-lethal dose of 2,4-D, MCPA or 2,4-DB herbicide causes many broad-leafed plants to wilt. This in turn makes them more palatable to grazing stock, which graze them in preference to the unaffected subterranean clover and grass species in the pasture.

Glyphosate and paraquat also appear to preserve the quality of some grasses. This makes pasture more attractive as dry feed, compared to untreated grasses.

The method*

**Please check the herbicide label at the time of purchase for the currency of this method.*

1. Six weeks after the opening rains in autumn, spray the infested area with 0.75 litres per hectare of 2,4-D amine (500 g/litre) for the control of annual thistles and Paterson's curse. Spray with 1.5 litres per hectare of 2,4-D amine if yellow burr weed (*Amsinckia* spp.), spear thistle or dock are present.
2. Seven days after spraying, stock the paddock with sheep at a minimum of four to five times the normal stocking rate for the district.
3. Leave the sheep at this high grazing pressure for about six weeks, or until the pasture shows signs of overgrazing.
4. Increase the stocking rate again in the spring to prevent any remaining weeds from flowering.

Although saffron thistle is an annual weed, its seeds germinate slowly throughout the autumn and winter months. For this reason, best results with this weed are obtained if 2,4-D amine is sprayed at 1.5 litres per hectare in early September, before any flowering stalks have formed. The heavy stocking rate should be applied seven days after spraying as described above.

Points to remember:

- The treated pasture must have a reasonably good legume base to compete with the weeds and to provide stock feed when the weeds are killed.
- At the recommended rates of application (0.75 litres/ha), 2,4-D will not severely affect the clover or other pasture species, nor will it kill any of the weeds listed. The spring rate (1.5 litres/ha) will delay flowering of subterranean clover. Medics will be killed at both rates.
- Heavy grazing is an essential part of this weed control method. Unless grazed, the weeds will recover from spraying in two or three weeks and make normal growth.
- "Spray-grazing" does not eliminate weeds from the pasture. However, if carried out correctly, the weed population will be reduced by the competition provided by the other pasture species.
- The spraying and grazing process may be repeated each year until the bank of dormant weed seeds is exhausted. However, in many cases only one treatment is needed to maintain a good balanced pasture.

Application of 2,4-D

1. The amount of herbicide to be applied is not as critical as the timing when a lethal dose of chemical is to be sprayed without grazing. This means that, although boom sprays are highly effective, misters, side delivery or triple nozzles may be accurate enough.
2. Do not exceed the recommended rate of application, as this may permanently damage the pasture.
3. There are gazetted areas in Western Australia where the use of 2,4-D is restricted or regulated by the granting of a permit (Section 3.6.2 & 3.6.4).

"Spray-grazing" is summarised in the following table (see over):

Table 1. Summary of spray-grazing recommendations

Weed	Time to spray	Rate 2,4-D (litres/ha)	Comments
Annual thistles & Paterson's curse	6 weeks after opening rains in autumn	0.75	Heavily graze with sheep, but do not overgraze
Amsinckia	As above	1.5	As above
Saffron thistle	Early September	1.5	As above, normal stocking in winter
Dock and spear thistle	6 weeks after opening rains in autumn	1.5	With spear thistle slash tops, spray regrowth when 15-20 cm high. Stock as above

CAUTION: Some burr medic varieties such as Serena, Circle valley, Santiago and *Medicago murex*, variety Zodiac etc., should not be "spray-grazed".

2.3.2 Spray-topping

"Spray-topping" in preparation for next year's crops and pastures consists of spraying pastures in spring, before most weeds have set viable seeds, in preparation for next year's crops and pastures. Weeds that flower over a short period of time make better targets for "spray topping" than those that flower over several weeks. Good control of weeds that flower over a long period may require more than one herbicide application. This treatment is particularly suitable for grasses.

For "spray-topping" to be effective you need to:

- Graze paddocks heavily, to prevent early seed head formation.
- Remove stock 2-3 weeks before normal flowering time, to allow even regrowth. This encourages weeds to flower at the same time.
- Apply herbicides:
  - Glyphosate* should be applied when grasses are flowering (Table 1)
  - Gramoxone* may be applied from flowering to the milky dough stage but before there are signs of haying off.
- A couple of days after spraying, graze the paddock. Sheep are as important after spraying, as before. They 'mop up' seed heads that may emerge following spraying.

*Glyphosate at 240-450 mL/ha (depending on formulation), Gramoxone® at 500 mL/ha and Spray.Seed® at 800 mL/ha were all registered for seed set control at the time of publication of this document. Oils and wetters may also be added. See product labels for full details.

Table 2. Effect of time of application on seed set

Treatment	Growth stage when herbicide applied	Seed Yield kg/ha	Viability
Nil	n/a	1170	90.6
Glyphosate (450 g/L) at 360 mL/ha	Bolting (head still encased in leaf sheath just prior to emergence)	410	85.3
"	Head Emergence	290	87.0
"	Flowering	90	59.0

When spraying, boom height should be set to ensure a double overlap of nozzle patterns at the height of the grass canopy. Apply in 60-150 litres/ha of water to give good coverage.

Pasture legumes (clover and medic) are also highly susceptible during flowering. "Spray-topping" may suppress legume seed set if they are flowering.

Where the soil weed seed bank is low, "spray-topping" may reduce substantially the need for weed control in a following cereal crop.

Research on the technique to wipe chemicals such as glyphosate and Gramoxone® using the blanket wipers has shown excellent results and this is currently being evaluated.

The phenoxy herbicides can be damaging to sensitive crops such as vines, tomatoes, canola and legumes. For this reason there is currently legislation in place to protect vine and tomato crops (see section 3.6.4 which deals with Restricted Spraying Regulations).

3 Herbicides

Herbicides are made up of various constituents. The main part is the active ingredient (see below). The herbicide also is made up of an inert carrier that has no herbicidal activity. In some formulations, a surfactant or emulsifier is added to improve the performance.

Active ingredient

The “active ingredient” of a commercial product is that part which produces a herbicidal effect. Active ingredient is expressed as grams per kilogram or per litre. For example, 2,4-D ester is usually sold in a formulation containing 800 grams of active ingredient per litre (800 g/litre).

3.1 Herbicide types

Many declared plants may be controlled by the use of “hormone”-like herbicides. These are all members of the chemical group known as phenoxy acids. The group contains, amongst others, 2,4-D in either the ester, amine or salt formulations. The ester form of these herbicides is generally the most active form, and also the most volatile, but there are situations when the other formulations are as effective. Table 3 lists the herbicide groups to which the herbicides belong.

Many recommended products are mixtures of herbicides, for example: picloram + 2,4-D (Tordon® 75D); picloram + triclopyr (Grazon DS®).

Information on herbicide trade names, active ingredients and chemical groupings can be obtained from the National Registration Authority's "PUBCRIS" product database at http://www.nra.gov.au/pubcris/subpage_pubcris.shtml.

Further information about chemical groupings and herbicide resistance can be obtained from Avcare at http://www.avcare.org.au/.

Table 3. Herbicide families

GROUP	Trade Name	Chemical Name
GROUP A - Inhibitors of fat (lipid) synthesis – ACC'ase inhibitors.		
Aryloxyphenoxypropionates ("Fops")	Correct® & Shogun®	propaquizafop
	Falcon®	butroxydim
	Fusilade®	fluazifop
	Fusion®	fluazifop + butroxydim
	Hoegrass®	diclofop
	Puma®	fenoxaprop + mefenpyr
	Targa®	quizalofop
	Topik®	clodinafop + propargyl
	Tristar®	diclofop + fenoxyaprop
	Verdict®	haloxyfop
	Wildcat®	fenoxyaprop
Cyclohexanediones ("Dims")	Achieve®	tralkoxydim
	Fusion®	fluazifop + butroxydim
	Select®	clethodim
	Sertin®	sethoxydim
GROUP B - Inhibitors of the enzyme acetolactate synthase – ALS inhibitors.		
Imidazolinones	Arsenal®	imazapyr
	Flame®	imazapic
	OnDuty®	imazapic + imazapyr
	Spinnaker®	imazethapyr
Sulfonamides	Broadstrike®	flumetsulam
	Eclipse®	metosulam
Sulfonylureas	Ally® & Brush-Off®	metsulfuron
	Cut-Out™	metsulfuron + glyphosate
	Glean®	chlorsulfuron
	Harmony® M	metsulfuron + thifensulfuron
	Logran®	triasulfuron
	Londax®	bensulfuron
	Monza®	sulfosulfuron
	Oust®	sulfometuron
	Titus®	rimsulfuron
GROUP C - Inhibitors of photosynthesis and photosystem II.		
Acetamides	Ronacil®	propanil
Benzothiadiazoles	Basagran®	bentazone
Nitriles	Buctril® 200	bromoxynil
	Buctril® MA (also contains MCPA - Group I)	bromoxynil + MCPA
	Jaguar® (also contains diflufenican - Group F)	bromoxynil + diflufenican
	Totril®	ioxynil
Pheny-pyridazines	Tough®	pyridate
Pyridazinones	Pyramin®	chloridazon
Triazines	Agtryne® MA (also contains MCPA - Group I)	terbutryne + MCPA
	Bladex®	cyanazine
	Gesagard®	prometryn
	Gesaprim®	atrazine
	Igran®	terbutryn
	simazine	simazine
Triazinones	Lexone® & Sencor®	metribuzin
	Velpar®	hexazinone
Uracils	Hyvar®	bromacil
	Krovar®	bromacil + diuron
	Sinbar®	terbacil
Ureas	Afalon®	linuron
	Cotoran®	fluometuron
	Graslan®	tebuthiuron
	Karmex®	diuron
	Tribunil®	methabenzthiazuron
	Tupersan®	siduron
GROUP D - Inhibitors of tubulin formation.		
Benzoic acids	Chlorthal®	chlorthal dimethyl
Dinitroanilines	Stomp®	pendimethalin
	Surflan®	oryzalin
	Treflan®	trifluralin
	Yield®	trifluralin + oryzalin
Pyridines	Visor®	thiazopyr

GROUP	Trade Name	Chemical Name
GROUP E - Inhibitors of mitosis.		
Carbamates	chlorpropham	chlorpropham
Organophosphorus	bensulide	bensulide
Thiocarbamates	Avadex® BW	triallate
	Eptam®	EPTC
	Ordram®	molinate
	Saturn®	thiobencarb
	Tillam®	pebulate
GROUP F - Inhibitors of carotenoid biosynthesis.		
Isoxazolidinones	Command® & Magister®	clomazone
Nicotinanalides	Brodal®	diflufenican
	Jaguar® (also contains bromoxynil - Group C)	diflufenican + bromoxynil
	Tigrex® (also contains MCPA - Group I)	diflufenican + MCPA
Pyrazoles	Taipan®	benzofenap
Pyridazinones	Solicam®	norflurazon
Triazoles	amitrole	amitrole
GROUP G - Inhibitors of protoporphyrinogen oxidase.		
Diphenyl ethers	Affinity®	carfentrazone
	Blazer®	acifluorfen
	Goal® & Spark™	oxyfluorfen
Oxidiazoles	Ronstar®	oxadiazon
GROUP H - Inhibitors of protein synthesis.		
Thiocarbamates	Saturn®	thiobencarb
GROUP I - Disrupters of plant cell growth.		
Benzoic acids	Banvel® & Cadence®	dicamba
Phenoxys	2,4-D	2,4-D
	2,4-DB	2,4-DB
	Barrel® (also contains bromoxynil and dicamba – Group C and Group I)	MCPA + bromoxynil + dicamba
	Buctril® MA (also contains bromoxynil – Group C)	MCPA + bromoxynil
	MCPA	MCPA
	Tigrex® (also contains diflufenican - Group F)	MCPA + diflufenican
	Tillmaster® (also contains glyphosate - Group M)	2,4-D + glyphosate
Pyridines	Garlon DS®	triclopyr
	Lontrel®	clopyralid
	Starane®	fluroxypyr
	Tordon® 242	picloram + MCPA
	Tordon® 75-D	picloram + 2,4-D
GROUP J - Inhibitors of fat synthesis.		
Alkanoic acids	propon	propon
GROUP K - Herbicides with multiple sites of action.		
Amides	Devrinol®	napropamide
	Dual Gold®	metolachlor
	Kerb® WP	propyzamide
	Ramrod®	propachlor
Amino propionates	Mataven L®	flamprop
Benzfurans	Tramat®	ethofumesate
Carbamates	Asulox®	asulam
	Betanal®	phenmedipham
	Carbetamex®	carbetamide
Nitriles	dichlobenil	dichlobenil
GROUP L - Inhibitors of photosynthesis at photosystem I.		
Bipyridils	Gramoxone®	paraquat
	Reglone®	diquat
	Spray.Seed®	diquat + paraquat
GROUP M - Inhibitors of EPSP synthase.		
Glycines	Roundup®	glyphosate
	Tillmaster® (also contains 2,4-D - Group I)	glyphosate + 2,4-D
	Touchdown®	glyphosate trimesium
GROUP N - Inhibitors of glutamine synthetase.		
Glycines	Basta®	glufosinate

3.2 Herbicide resistance

Herbicide resistance is the ability of plants (weeds) to survive when treated with a herbicide that would normally kill them. Resistant weeds initially develop within a population by mutation. Without any external influences these mutant plants will exist in very small numbers (about one in a million), and are usually identical in appearance to the normal population. When a herbicide is applied most of the susceptible plants are killed, leaving the resistant plants to set seed freely. After several applications of the herbicide there are no susceptible plants left, and so there is no control because only the resistant plants remain. The time taken for resistance to develop is usually influenced by:

a) Initial frequency of resistant genes - If a herbicide has several sites of action within a plant, there will be very few resistant plants in a normal population.
b) Selection pressure - The more efficient the herbicide (it kills a larger percentage of the weeds present) the quicker will be the development of resistance.
c) Fitness - If the resistant plants are not as vigorous as the susceptible plants, then they will take longer to dominate because they will have to compete against the stronger plants.
d) Seed Dormancy - The higher the seed dormancy exhibited by the weed, the longer it will take for resistance to develop fully. This is because large numbers of non-resistant seeds will appear in successive years to dilute the population of resistant plants.

In Western Australia herbicide resistance has developed in annual ryegrass and to a lesser extent in wild oats and wild radish. The declared plant Paterson's curse developed resistance on several properties after multiple applications of a sulfonylurea herbicide. Resistance has been detected in barleygrass and capeweed in other States. In the USA, weeds of corn crops have developed resistance to atrazine and kochia has developed resistance to the sulfonylurea group of herbicides. Some 60 weeds have been reported as having resistance in western and eastern Europe. One of the reasons why the salt tolerant pasture plant kochia from the USA was declared by the APB was because of its potential to develop herbicide resistance.

Herbicide resistance can be slowed down by:

a) Rotating the herbicide group being applied (see Table 3). Often the weed is only resistant to one herbicide group, so by changing to different herbicide groups the development is slowed. This may involve modifying the cropping rotation to allow the use of a different herbicide.
b) Preventing seed formation. This can be done using herbicides such as Spray.Seed® or glyphosate for "spray topping" or by cutting for hay, heavy grazing, or harvesting the seed.

Resistance to chlorsulfuron has been detected in WA. It should be used for declared plant control with caution in the cereal growing areas, and an alternative herbicide should be used where herbicide resistance in ryegrass has been found.

Further reading: Anon (2001). Herbicide resistance and World Grains. Eds: Powles, S.B. and Shauer, D.L. CRC Press.

3.3 Application of herbicides

Read the label

Study the label before you open the container. Some materials require great care in handling, and a few minutes spent noting any precautions listed on the label may save considerable trouble later. No matter what equipment you use, think about the risk of damaging nearby plants. The person who applies a herbicide may be held responsible for any damage that occurs.

Some herbicides are supplied as wettable powders. These must be kept in suspension during spraying. When spraying wettable powders, efficient agitators are required in the supply tank to prevent the powder settling back to the bottom of the tank. Make certain you use the jets and filters recommended by the manufacturer.

Accuracy of application

A boom spray is the most accurate way of applying herbicides; therefore it should be used whenever possible. The accuracy of spot spraying depends largely on the operator's speed of walking and accuracy in estimating "the point of run-off". Misting is even less accurate; it depends on the experience of the operator and on the wind speed.

3.3.1 Boom spraying

Boom sprayers are used when relatively large areas of weed-infested land need treating, and where the weed is small enough and the terrain level enough to allow it to be used. The rate of herbicide to be sprayed is expressed in litres or kilograms of product per hectare. The amount of herbicide actually being applied can only be accurately determined by properly calibrating the boom spray before starting (see section 3.5). Boom sprays generally apply a relatively low volume of water per hectare, usually between 30 and 200 litres/ha, at pressures between 150 and 300 kilopascals. They are widely used to selectively control weeds in cereal crops and pastures and for applying 'knockdown' herbicides in minimum, zero or no tillage cropping.

3.3.2 Spot spraying

Spot spraying consists of treating each weed individually. It can be carried out either by a knapsack sprayer or a hand-lead from power equipment. Knapsacks are used to spray small isolated weed infestations. Recommendations are shown as the quantity of herbicide product (in millilitres or grams) to add per litre of dilutent (carrier) (water or distillate). The volume of output is variable, depending on the speed of spraying, but is generally between 1000 and 1500 litres/hectare.

Hand-lead equipment is used to spot-spray more extensive areas of weeds that are too sparse to warrant boom spraying, or where the terrain is too rugged to allow the use of a boom spray.

Rates of application are usually expressed on a volume basis. That is, the number of litres of carrier fluid (water or diesel fuel) with which one litre (or kilogram) of chemical products should be mixed. This type of equipment usually applies volumes of between 1000 and 1500 litres of spray per hectare. The pressure used depends on the type of hand-lead, the weed to be sprayed and the herbicide chosen. Avoid using pressures greater than about 500 kilopascals because this may produce small droplets that are likely to drift.

When spot spraying it is important to wet the foliage thoroughly. Do not waste chemical by spraying after the mixture starts to run off the leaves - spray to "the point of run-off" and no more.

Hand wands and spray Guns

It is just as necessary to accurately calibrate hand wands and spray guns as it is to calibrate boom sprays and misters. The following factors determine how much spray material is applied:

1. the skill and speed of the operator,
2. pressures used,
3. type of growth, and
4. nozzle size used.

Invariably, the greatest cause of failure is application of too much or too little chemical. Do not use a fixed ratio, for example, 1:100 mix. It is important to calibrate each time.

It is essential to ensure that the amount of chemical being applied is as close to the recommended rate as possible. Both the operator and the equipment need to be calibrated. This is important as spray operators have different styles and one would not treat an area in the same time as another.

For best results with hand wands:

1. apply the recommended amount of active ingredient per ha, and
2. apply in a **minimum** quantity of water to obtain complete foliage cover without excessive run-off. That is, spray to the point of run-off **not** beyond.

3.3.3 Misting

Misting consists of pumping spray solution into a high speed stream of air. This air blast breaks the solution up into small droplets. Large areas of infested land, particularly on difficult terrain, can be covered relatively quickly without needing large volumes of dilutent (carrier). However, the large number of small droplets produced by misters can cause problems if the spray droplets drift onto susceptible plants. Check both the direction and speed of the wind before spraying. It is important to check the output and effective coverage of the mister under the conditions prevailing on the day of operation as wind speed is the factor most likely to affect the swath width. Output may also vary, depending on the type of material being used. See section 3.5.4 for how to calculate swath width.

Avoid using ULV (ultra-low-volume) misters close to susceptible crops.

Power mister Do’s and Don’ts

- DO set the discharge orifice to point 45° upwards.
- DO always operate from downwind to upwind of the crop. Make the next run further towards the direction the wind is coming from.
- DO stop operations if the wind falls to less than 5 km/hr or rises to more than 13 km/hr.
- DO ensure proper agitation of the mixture in the tank.
- DO NOT operate the vehicle at more than 5 - 8 km/hr due to the effect of its slipstream on air movement.
- DO NOT apply a swath width greater than 10 metres until experienced with the machine.
- DO NOT use misters to apply diquat, paraquat, glyphosate or wettable powders.

3.3.4 Weed wiper

These units work on the principle of a herbicide-soaked rope or blanket being drawn across a crop or pasture so that the taller weeds receive a dose of herbicide leaving the shorter pasture or crop species unaffected.

The advantages are:

- there is no spray drift (operator and environmental safety are therefore increased),
- herbicides can be applied in windy conditions, and
- less chemical is used because it is only applied to the target plant.

Disadvantages are:

- slower speeds are necessary to apply herbicides effectively,
- dense infestations may require a double pass, and
- dirt reduces the effectiveness of some herbicides.

When glyphosate (Roundup®) was first marketed, weed wipers became commercially feasible. Many different types of rope wick applicators were made and evaluated in the 1970s and early 1980s.

Trials in Western Australia at that time showed that glyphosate could be wiped on to cape tulip, rushes and bracken and give reasonable control. However, there were a number of problems with rope wick applicators including:

- high cost (up to $1000/metre of width),
- slow operating speed, and
- ropes could be torn out of the chemical reservoir, wasting expensive chemical.

For these reasons the units were not very successful.

More recently the same principles have been used to apply both glyphosate and some of the newer products, such as the sulfonylureas (Glean®, Ally®, Oust®). However, instead of using ropes to wipe on the chemical, a strip or blanket of absorbent material is now being used.

Blanket wipers

Blanket wipers are very robust, effective and cheap to build as well as being sparing in chemical use. Therefore some farmers are taking a second look at weed wipers. In particular farmers are enthusiastic about the very good results obtained using the sulfonylureas on cape tulip and more recently Paterson's curse and arum lily.

You can buy blanket wipers commercially, but some farmers have decided to build their own.

The advantages are:

- they are simple to build and use,
- home-made units are cheap to construct,
- units are light and robust with no moving parts, and
- blankets are easily cleaned and renewed if necessary.

Disadvantages are:

- Blankets may become dirty and clogged, and
- for blanket swath widths greater than 6m, units must be supported on the ends with wheels or skids.

See Farmnote 90/96 "Blanket wipers for tall weed control" by John Peirce and Brad Rayner.

3.3.5 Wide angle/side delivery - single or multiple head nozzles

These are mainly used for roadside and firebreaks. They operate at high pressure and volume of application and produce a swath of 3-5 m depending on nozzle arrangement. Spraying through fence lines is one benefit of this type of nozzle.

3.3.6 C.D.A. sprayers

A CDA (Controlled Droplet Applicator) sprayer works by having the pesticide fall onto a spinning disc that has a row of fine teeth around the perimeter. The spinning motion of the disc forces the liquid out to the edge of the disc and the fine teeth help to break up the liquid into droplets of a very even size.

CDA sprayers may be used for continuous or spot spraying of contact, residual or selective herbicides. The volume discharged varies according to the nozzle size selected and can vary between 10 and 20 litres per hectare at an average walking speed of 3 km/hr.

When the head is held 200 mm above the target plants the swath width is 1.2 metres.

The droplet size is controlled to about 250 microns (1000 microns equals 1 millimetre). Select the one of three nozzles supplied which maintains a flow rate of 1 mL per second through the nozzle. The flow rate will vary depending on the viscosity of the formulation.

Do not spray when the wind speed is less than 5 km/hr or more than 25 km/hr. Always spray from the upwind side of the target.

3.3.7 Herbicide performance

A number of important principles affect the performance of a herbicide on a weed and on the environment.

- Make sure you apply the **correct rate** of herbicide. Regularly calibrate the spray equipment, and check the output of the nozzles particularly after using abrasive chemicals. Nozzles wear out, and should be replaced if their output is more than 5 per cent above or below the correct output. It is also important to check at regular intervals that each nozzle is distributing spray evenly.
- **Spray as evenly as possible** at all times. This is particularly important when spot spraying or when using a mister.
- **Spray in light wind** conditions if possible. This ensures that as much herbicide as possible reaches the target plants, and minimises the danger of drift on to desirable vegetation.
- Spray weeds at the **correct size or stage of growth**.
- Spray weeds when they are **actively growing**. This will ensure maximum uptake and translocation of the herbicide. Weeds should not be sprayed when they are under stress, either through lack of water (drought), too much water (waterlogging), disease, insect or mechanical damage.
- **Avoid spraying when it's raining** or likely to rain. Herbicide may be washed off the leaves before it can be absorbed. This does **not** apply to soil-active, root-absorbed herbicides where rainfall may be necessary before the chemical takes effect.
- **Do not apply a higher volume** than necessary. Contact herbicides need to thoroughly wet the weed, to the point of run-off. Translocated herbicides do not need such thorough coverage. Soil-active herbicides do not need to cover the plant at all, but an even application over the soil is desirable.
- **Do not use more surfactant** (wetting agent) than is recommended, otherwise too much spray mix may run off from the leaf surface. Moreover, it may cause the spray to form large amounts of foam in the spray tank, leading to difficulties in application.
- **Do not apply at a higher pressure** than you need to obtain good coverage of the plant. High pressure may generate excessive numbers of small droplets in the spray, which increases the danger of droplets drifting on to non-target plants, and increases the hazard to the operator.

3.4 Chemical safety

3.4.1 Toxicity of herbicides

The herbicides recommended can be safely used, provided you take appropriate precautions as required by the chemical label or Material Safety Data Sheet.

Pesticides usually have several toxicity ratings. They are: oral; dermal; acute and chronic.

The oral toxicity of a herbicide is determined by feeding it to groups of laboratory animals at various doses. From these trials the LD_{50} value is calculated. This is the amount of chemical, expressed as milligrams of active ingredient per kilogram of body weight, required to kill 50 per cent of the animals tested. The figures used in the table refer to rats. Remember, the lower the LD_{50} number, the more toxic is the chemical.

The acute LD_{50}'s (rats) given for herbicides commonly used in Western Australia are taken from "The Pesticide Manual: a world compendium" (12th edition) which is published by the British Crop Protection Council.

Table 4. Oral LD_{50} of some well known compounds

Caffeine	150 mg/kg
DDT	420
Aspirin	750
Penicillin	1000
Salt	3000
Petroleum oils	1000 - 10000

Table 5. LD_{50} of some well known herbicides

Trade name	Active ingredient	Oral LD_{50} mg/kg	Dermal LD_{50} mg/kg
Poison schedule: S7 (restricted availability)	**Hazard rating:** Extreme	**Label statement:** Dangerous Poison S7. Not to be taken, keep out of reach of children. Read safety directions before opening.	
Gramoxone®	paraquat	112 - 150	911
Spray.Seed®	paraquat + diquat	150	911
DSMA	DSMA	1,800 - 2,800	>10,000
Poison schedule: S6	**Hazard rating:** Moderate	**Label statement:** Caution. Not to be taken, keep out of reach of children. Read safety directions before opening.	
Bromicide®	bromoxynil	190 -270	>2,000
Reglone®	diquat	230 - 440	>793
Garlon™	triclopyr	713	>2,000
Tordon™ Double Strength	triclopyr + picloram	n/a	n/a
MCPA	MCPA	800	>4,000
Ramrod®	propachlor	1200	>20,000
Hoegrass®	diclofop-methyl	481 - 693	>5,000
Eclipse®	metosulam	>5000	>2,000

(continued over page)

Common name	Active ingredient	Oral LD_{50} mg/kg	Dermal LD_{50} mg/kg
Poison schedule: S5	**Hazard rating:** Slight	**Label statement:** Warning. Keep out of reach of children.	
2,4-D	2,4-D	639 - 764	>1,600 - 2,400
Tordon™ 75D	2,4-D + picloram	n/a	n/a
MCPB	MCPB	4,700	>2,000
2,4-DB	2,4-DB	700	n/a
Kamba, Banvel™	dicamba	1,707	>2,000
Amitrole	amitrole	1,100 - 24,600	>2,500 - 10,000
Terbutryn	terbutryn	500 - 2,500	>2,000 - 20,000
Velpar®	hexazinone	1,690	>5,278
Atrazine	atrazine	1,869 - 3,090	>3,100
Basta®	glufosinate	2,000	>4,000
Tigrex®	diflufenican	>2,000	>2,000
Tribunil®	methabenzthiazuron	>5,000	>5,000
Trifluralin	trifluralin	>5,000	>5,000
Roundup®	glyphosate	5,600	>5,000
Lontrel™	clopyralid	>4,300	>2,000
Simazine	simazine	500 - 10,000	>2,000
Glean®, Lusta™ etc	chlorsulfuron	5,545	>2,500
Poison schedule: Unscheduled	**Hazard rating:** Very slight	**Label statement:** Keep out of reach of children - optional Harmful if swallowed - optional Caution - optional	
Linuron	linuron	1,000-4,000	>2,000
Starane™	fluroxypyr	2,450	>5,000
Casoron®	diclobenil	2,700-6,000	>2,000
Diuron	diuron	3,400-3,700	>2,000
Propon	2,2-DPA	3,860-9,330	>2,000
Londax®	bensulfuron	>5,000	>2,000
Broadstrike™	flumetsulam	>5,000	>2,000
Arsenal®	imazapyr	>5,000	>2,000
Spinnaker®	imazethapyr	>5,000	>2,000
Ally®/Brush-off®	metsulfuron methyl	>5,000	>2,000
Logran®	triasulfuron	>5,000	>2,000
Hyvar® X, Bromacil	bromacil	2,000	>5,000
Tordon™ Granules	picloram	8,200	>2,000

Although the toxicity of some herbicides varies with the route of entry into the body (oral, inhalation, dermal), in general, the acute oral LD_{50} figures gives a good indication of the relative toxicity of the herbicide. The poison schedule is dependent on other factors as well as LD_{50} of the product. For example, all arsenics are carcinogenic and hence are placed in the S7 category.

Acute toxicity is the toxicity of a single dose, such as could happen in a chemical spill onto the skin or by accidental spilling. Chronic toxicity is the long-term toxicity of a chemical after repeated low-level exposure for an extended period.

The solvent or emulsifier used often increases the toxicity and makes the compound far more harmful than the pure chemical.

Bulletin 4243 "Management of Agricultural Weeds in Western Australia", Section 13, provides more detail on toxicity of herbicides.

3.4.2 Storage of herbicides

Take care that herbicides are stored safely when not in use. Most cases of pesticide poisoning occur in children who have been allowed to play with herbicide containers. Accidents are avoidable if commonsense precautions are taken.

Safe storage of herbicides

- Store all herbicides in a locked storage cupboard or shed set aside for that purpose.
- Do not store near foodstuffs, seeds or fertilisers.
- Keep herbicides only in their original labelled container. Never store in drink bottles or unmarked containers.
- Seal containers adequately and store them in relatively cool conditions for maximum storage life.

3.4.3 Handling herbicides

Hazard

The use of a chemical becomes hazardous (irrespective of its toxicity) if it is formulated or used in such a way that human exposure is increased and poisoning occurs.

The relative hazard of pesticides can be readily judged from the signal words that appear at the top of the principal panel of the label of the pesticide container. These words must appear on pesticide labels (see Table 5).

Exposure

There are three main ways chemicals can enter our bodies.

(i) Skin absorption (dermal)

Skin absorption is responsible for the majority of occupational poisonings. Spraying without protective clothing and general carelessness when mixing and spraying are responsible for most poisoning cases in this group.

(ii) Inhalation (breathing)

No protective equipment, mixing chemicals in a badly ventilated space, and working downwind when spraying is responsible for inhalation of chemicals.

(iii) By mouth (oral)

Chemicals may be swallowed when eating with contaminated hands, smoking and blowing or sucking to clear blocked nozzles on the spray unit.

Children sometimes poison themselves by drinking chemicals left within their reach. All chemicals should be properly stored.

3.4.4 Protective clothing

Gloves

- Unlined, flexible gauntlet-type gloves are considered best.
- PVC (not rubber or surgical plastic gloves) Viton and Nitrile Rubber (N.B.R.) are impervious to most solvents and are most suitable.
- Disposable/surgical gloves are suitable only for delicate jobs such as cleaning nozzles, provided they are used once only, and then disposed of properly.
- Replace used gloves regularly.
- Never wear leather gloves, or gloves that leak.

Overalls

- Full length overalls should be worn during all spraying operations. Light cotton/polyester type is available for summer. These must be washed every day. Bib and brace type are not suitable.
- Full length breathable nylon fabric overalls are excellent.
- P.V.C. pants and jackets are very good when spraying in winter. They are essential for the more hazardous horticultural spraying operations.
- There are several disposable overalls on the market now. TYVEK (disposable) is very comfortable, easy to wear and effective. Polyethylene and polypropylene fabric will prevent droplets from spray drift contacting skin, but are not waterproof.

Boots

- While rubber boots are satisfactory, PVC boots are better. Steel caps in the toe offer extra safety but are not essential when spraying.
- Never wear leather boots while spraying and throw out leaking boots.

Eye and face protection

- Always wear eye protection when handling, especially when pouring chemicals and solutions.
- A face shield protects the whole of the face but is difficult to wear with the conventional twin cartridge respirator.
- Goggles and safety glasses protect only the eyes. However, they can be worn with a respirator.

Aprons

Most operators wear only cotton overalls while spraying. PVC aprons are quick to put on before chemical drums are lifted for pouring. Any spillage can be quickly washed off without affecting the overalls. Aprons should cover from the shoulder to below the top of the boots.

Respirators

- The half-face twin cartridge respirator usually meets most spraying requirements. They come in three sizes to suit various faces.
- The half-face single cartridge is satisfactory but the cartridge should be changed more often than the twin cartridge mask.

Respirator cartridges

The multipurpose agricultural filter is the best for general spraying. It contains both a cotton filter and activated carbon to remove both dust and organic solvent vapour.

Cotton and paper masks are satisfactory for removing dusts but are not suitable where organic solvents are used. Only activated carbon will remove these vapours.

The dust filters are full when it becomes hard to breathe. Activated carbon filters are full when the operator can “smell” the chemical being used. They can be tested by trying to smell perfume through the mask. If you can smell the perfume replace the filters. (This is assuming the mask has a snug fit on the operator’s face.)

Operators with heavy beards are likely to find difficulty obtaining a proper face fit.

Activated carbon filters must be stored in a convenient sealed container such as a plastic lunch box to maximise their useful life. If left out they will continue to absorb organic vapours like diesel and petrol.

For added protection

- Always carry at least 20 litres of water, soap and paper towelling with the spray outfit for washing hands, face and other areas of exposed skin, and especially your eyes.
- Wash thoroughly with soap and water after mixing chemicals and before eating, drinking or smoking or after work.
- Barrier cream may be used on the hands but is not a protection against chemical penetration.

3.4.5 First aid

- If you feel dizzy, nauseous, have severe headaches, disturbed vision or stomach upsets within a few days after handling herbicides - SEEK MEDICAL ADVICE - tell the doctor all you know about the chemical used.
- For immediate first aid treatment - read the label on the container.
- When using pesticides consistently - HAVE REGULAR MEDICAL CHECKS.
- In case of emergency the Poisons Information Centre is open 24 hours a day and can be contacted for the cost of a local call on 131126.

POISONS INFORMATION CENTRE	24 Hour hotline	ph: 131126

3.4.6 Disposing of empty containers and unwanted herbicide

Empty containers

- Rinse empty containers three times with water and tip rinseate into spray tank. This is best done as the containers are emptied during spraying operations.
- Never use chemical containers for water storage or livestock feed troughs. Take returnable containers to your nearest DrumMuster depot - contact your Shire for details.
- Non-returnable containers:
  - Never burn any herbicide container. They may give off poisonous smoke or damage nearby plants or crops.
  - Chop holes in top, bottom and sides of metal containers, crush under tractor wheel or flatten with a sledge hammer so that they cannot be reused nor collect water. Do not use oxy-acetylene torches to cut holes.
  - Crush metal, plastic, cardboard or fibre drums and break glass containers, then bury them at least 0.5 metre deep at a safe site. Do not bury them in water courses or where they might contaminate water supplies.

Unwanted pesticides

Only mix enough pesticide to do the job.

If you have unwanted pesticides, firstly offer contents for use by a responsible person. If this is not possible, select a well-drained site away from desirable vegetation, and where lateral movement of ground water will not occur. Dig a pit at least 0.5 m deep, spread a bag of lime in the bottom and pour the diluted pesticide over the lime. Then cover with soil. Permanently mark the site and show it on your map of the area.

Never incinerate unwanted pesticides.

For more information on the safe use of herbicides:

1. See Bulletin 4527, "Code of Practice for the Use of Agricultural and Veterinary Chemicals in Western Australia". This is available from the Department of Agriculture.

2. Become an accredited 'ChemCert' chemical user by taking a course in your area. Contact your local re-seller or telephone Terry O'Beirne on (08) 9341 5325.

3.5 Calibration of spray equipment

Calibration is the process of calculating the volume of a carrier (such as water) applied over a given area. This allows us to calculate accurately the correct rate of the pesticide to be applied.

The actual volume of spray applied will vary with the type of equipment, chemical and the density and height of the vegetation. For instance, low volume (30-50 litres/ha or less) is adequate for chemicals that are translocated by the plant (eg. phenoxy herbicides, glyphosate), but higher volumes may be necessary for contact herbicides such as paraquat or diquat which must adequately cover the foliage. While 50 litres/ha is adequate on closely grazed pastures, and on young weed growth, 100 litres/ha or more may be necessary for dense and tall growth. Coverage is largely determined by droplet size and the number of droplets reaching the target.

Poor results from weed spraying are rarely the fault of the chemical. The usual reasons are incorrect application rate or unfavourable conditions at the time of application.

Most modern sprayers now have their speed and flow rates computer controlled. However, at some time a check should be made to determine whether the correct volume of pesticide is being sprayed.

3.5.1 Power-driven boom spray

Factors controlling the volume of spray applied per hectare are:

1. nozzle size,
2. nozzle spacings,
3. pressure, and
4. speed of travel.

Every spray unit should be serviced, cleaned and calibrated at the start of a spraying program. Check calibrations during the program.

There are a number of ways of calibrating a unit but only one is shown here. Because of the variation in nozzle output, it is not satisfactory to just read the output from the manufacturer's chart, particularly if the machine has previously done a lot of spraying.

Checks, maintenance and calibration

1. Remove all nozzles and strainers, soak in water and clean them with compressed air, a soft brush or an old toothbrush. Do not use wire or pins to clean the nozzle tip orifice.
2. Flush out the tank and boom with clean water while nozzles are out.
3. Replace nozzles but do not over-tighten. Offset each nozzle about 10°-15° to prevent adjacent fan patterns colliding.
4. Start pump and motor and set the pressure to operate between 150 and 275 kPa (22 to 40 psi) depending on the manufacturer's recommendations for the nozzles used.
5. Run the pump, collect and measure the amount of spray put out in one minute by each nozzle. Record the outputs and find the average.
6. Discard any nozzle that differs from the average by more than 5 per cent. Replace and measure the output of the new nozzle. It is also important to check the fan pattern of each nozzle for even spray distribution. There should be no streaks or gaps in the fan pattern.
7. When a reasonably uniform set of nozzles has been selected, add up the total output of all nozzles on the boom in litres used per minute.
8. Measure the swath width of the boom. This is the distance between the first and the last nozzles plus the distance between any two nozzles.
9. Level the boom and set at correct height. Allow a double overlap, ie each nozzle overlaps into half the neighbouring nozzle. With 500 mm nozzle spacings and 80° flat fan nozzles the boom height should be about 45-55 cm and 35-50 cm for 110° flat fan nozzles. At the lower pressures fan angle tends to decrease so height of boom needs to be raised to maintain correct overlap.
10. Speed of spraying: Maintain a constant and accurate speed of travel whilst spraying. This is possibly the most important factor in the accurate application of herbicides.

    The following method can be used to determine speed:

    1. Measure out 100 metres.
    2. Set throttle and gearbox at selected operational setting.
    3. Time sprayer over 100 metres.
    4. Divide number of seconds taken over 100 metres into 360. This is equal to speed in kilometres per hour.

    Note: A tachometer is essential for accurate reproduction of the calibrated speed under working conditions. Alternatively the throttle must be set in a fixed position.

    Calculate the volume applied in litres per hectare. Given the desired speed in km per hour, swath width in metres and boom output rate in litres per minute apply this formula:

$$\text{sprayer output (litres/ha)} = \frac{600 \times \text{output of boom (litres/min)}}{\text{swath width (m)} \times \text{speed (km/hr)}}$$

This formula is based on the fact that a one metre wide sprayer travelling at one kilometre per hour will cover one hectare in 600 minutes (1/600 ha/min):

Example:

Boomspray has 30 nozzles at 500 mm spacings.
Each nozzle discharges (on average) 425 mL/min. Total boom discharge is therefore 0.425 litres x 30 = 12.75 litres/minute.
Swath width is 15 metres.
Speed selected for job is 10 kilometres per hour.

$$\textit{Sprayer output} = \frac{600 \times 12.75 \textit{ (boom output)}}{15 \textit{ (width)} \times 10 \textit{ (speed)}} = 51 \textit{ litres/ha}$$

To calculate required speed:
Given the discharge rates of individual nozzles in litres per minute and the volume required per hectare, the required speed can be calculated as follows:

$$\text{Speed} = \frac{600 \times \text{boom output litres/min}}{\text{spray volume required/ha} \times \text{swath width}}$$

Example:

Boomspray has 30 nozzles at 500 mm spacings and each nozzle discharges an average of 0.425 litres (425 mL) per minute at operational pressure. Therefore the boom output is 30 x 0.425 = 12.75 litres/min.
You want to apply the herbicide in 50 litres of water per hectare. How fast do we need to travel to obtain this volume?

$$\textit{Speed} = \frac{600 \times \textit{boom output}}{\textit{rate/ha} \times \textit{swath width}}$$

$$= \frac{600 \times 12.75}{50 \times 15.5} = 9.87 \textit{ km/hr}$$

$$\textit{Time to cover 100 m} = \frac{360}{9.87} = 36.5 \textit{ secs.}$$

See APB Infonote 14/88

3.5.2 Ground-driven boom sprays calibration

Ground-driven boom sprays require regular maintenance like all farm equipment. They also require calibration.

Checks, maintenance and calibration:

1. Check tyre pressure. Tyres must be kept at the right pressure to ensure the correct number of wheel revolutions per hectare (for Computor sprays 18 p.s.i. or 124 kPa).

Speed (km/hr)	Time to travel 100m (sec)
6	60
7	51
8	45
9	40
10	36
11	33
12	30
15	24
18	20
20	18

2. Check the agitator jet in the bottom of the spray tank regularly for blockages, excessive wear or corrosion. Fit a trickle irrigation filter in the agitator line to reduce the chance of blockage.

   Blockage causes an increase in the volume of spray applied by the nozzles and prevents agitation during spraying. If the jet is enlarged, the output of the boom decreases. Fit a liquid-filled pressure gauge (0 - 600 kPa) to the agitator line. Maintain a pressure of between 200 and 350 kPa while working using standard nozzles. Any pressure rise indicates the agitator jet, tip filter or nozzle is blocked.

   For Computor sprays, standard wire gauge drill bits may be used to clear blockages, but check the correct size for your model with the manufacturer. A small sliver of wood such as a toothpick would be safer. Any increase in size of the agitator jet will reduce the amount of liquid being delivered to the booms.

3. The pump should be maintained regularly. Fluid discharging from the cover plate on the rear of the pump is a sign of severe wear. A low reading on the pressure gauge also indicates a worn pump.

4. Take out all nozzles and filters and soak in water. Use a nylon brush such as a toothbrush for cleaning. Never use a wire brush as this will damage the holes.

   Wear may produce an uneven fan pattern for which the only solution is a new nozzle. A complete new set of brass nozzles will be needed about every two years for average farm use, more frequently if flowable powder chemicals are used extensively. Other materials such as sintered alumina or hardened stainless steel, acetal plastic or a hard coated nozzle are better than brass.

5. Flush out the tank and boom with clean water while the nozzles are out.

6. Replace the nozzles, taking care not to over-tighten. Offset nozzles 10° to the boom so that adjacent fans do not interfere with each other. Set them at opposite angles on each wing so the pattern can be seen from the tractor seat.

7. Supply water to the boom under pressure from a fire fighter pump or the water mains and check the nozzles in operation. Replace any which differ from the average output by more than 5 per cent or show streaks in the fan pattern.

8. If the agitator line feeds from the boom line, replumb (see APB Infonote 15/88) and fit a flowmeter to measure output to the boom.

   If the agitator line arises before the boom, the flowmeter can be placed to read the boom output directly.

   Record the flow over a measured run (at least 400 metres). Drive around in a circle in the paddock before starting the run to ensure that all lines are full.

   The flowmeter measures the spray output used in the formula below.

9. Now calculate the sprayer output using this formula:

   $$\text{Spray output (litres/ha)} = \frac{\text{Output}}{\text{Area}}$$

Example:

Swath width = 12.2 metres
Length of run = 400 metres
Output of all nozzles during run = 23 litres
Area covered = 12.2 x 400 = 4880 m^2 = 0.48 ha

$$\text{Output in litres/ha} = \frac{23 \text{ litres}}{0.48 \text{ hectares}} = 47.9 \text{ litres/ha (say 48 litres/ha)}$$

10. Next work out the amount of chemical to add to the tank:

$$\text{Amount of chemical} = \frac{\text{Capacity of tank x rate of chemical to be applied/ha}}{\text{Sprayer output (litres/ha)}}$$

Example:

Tank capacity = 1000 litres
Recommended rate of chemical = 750 mL/ha (0.75 litres/ha)
Output calculated above = 48 litres/ha

$$\text{Amount of chemical needed to be added to tank} = \frac{1000 \times 0.75}{48} = 15.6 \text{ litres}$$

11. Set the boom at the correct height. The fan pattern for each nozzle should overlap exactly half-way, at target (weed) height.
12. One final check - the speed. Keep between eight and 15 km/hr. At higher speeds too many fine droplets are put out. If the speed is excessive the pressure gauge will show a high reading. Small droplets may drift off target, wasting chemical and perhaps damaging susceptible crops. Keep the spraying pressure at 200 - 300 kPa.

    Speed may be calculated by timing travel over a known distance

$$\text{speed (km/hr)} = \frac{\text{distance (m) x 3.6}}{\text{time (sec.)}}$$

Boom spray storage

When you have finished your spraying program for the season flush out your boomspray with clean water, removing nozzles and strainers for thorough cleaning. Run a mixture of water and soluble oil (eg. crop oils) through your pump relief valve and nozzles. Soluble oil is available from fuel depots.

Support the boom so that it will not be damaged by other machinery.

3.5.3 Wide Angle And Side Delivery Nozzles Calibration

Measure the water put out in 1 minute, then use the formula:

$$\frac{\text{litres water used in 1 min. x 600}}{\text{width of spray swath (m) x speed (km/hr)}} = \text{Output in litres/ha}$$

3.5.4 Mister calibration

Method 1

Fill the tank with water and run the mister at operational speed for exactly one minute. Then measure the quantity of water needed to refill the tank to exactly the same point.

$$\text{Output in litres/ha} = \frac{\text{litres water used in 1 min. x 600}}{\text{distance between each run (m) x speed (km/hr)}}$$

The most important factor is the calculation of swath width. Some manufacturers have special cards for collecting droplets to determine if a uniform deposition is occurring. For best results use these droplet capture cards if available. Although the swath may appear to drift for a considerable distance the very fine droplets may not be landing. It is much better to work on a fixed swath width and calculate the amount of chemical needed consistently regardless of how far it appears to be going on a windy day.

Use 30 - 40 m swath width with ULV (ultra low volume) formulations and 20 - 30 m with EC (emulsifiable concentate) formulations. For most applications a deposition of 20 - 30 droplets/cm^2 is necessary to achieve control of the target organisms.

Method 2

Place a tube over the delivery nozzle and collect the output for one minute. If using ULV chemicals, first check using distillate. Do the final calculations wearing full safety equipment with the neat chemical or chemical distillate mix. The output will vary slightly depending on the viscosity of the chemical.

3.5.5 Handwand and spraygun calibration

Step 1. Spray volume applied/ha

1. To measure sprayer output, mark off an area 10 metres x 5 metres (ie 1/200 ha) typical of the area to be sprayed.
2. Select pressure - usually 500-700 kPa.
3. Record the time it takes to spray measured area to point of run off.
4. Discharge spray into a bucket for the same period of time. Record volume put out in litres. This is the sprayer output on 1/200 ha. Multiply this by 200 to give volume per hectare.

Step 2. Amount of chemical to add to tank

1. Find tank capacity in litres.
2. Find recommended pesticide application rate in litres/ha.
3. Measure sprayer output in litres/ha (above).
4. Chemical you need to add to the tank $= \frac{\text{tank capacity x chemical rate}}{\text{sprayer output}}$

3.5.6 Calculation of pesticide in spray tanks

Having first calibrated the equipment to be used for the spray operation, the next step is to calculate the amount of pesticide to add to each tankful.

1. Record calibration results
2. Calculate the volume of spray tank if you don't know it from the handbook:

   For square or rectangular tanks:

   Multiply length (m) x breadth (m) x height (m) to give volume in cubic metres.

   For cylindrical tanks:

   Multiply π (3.14) x radius squared x length to give volume in cubic metres.

   For spherical tanks:

   Multiply 4/3 x π (3.14) x radius cubed to give volume in cubic metres.

   Multiply resulting volume of the tank in cubic metres by 1000 to give capacity of tanks in litres. One cubic metre = 1000 litres
3. Find the recommended application rate of product.

   This may be expressed as volume or mass, eg. litres, millilitres or kilograms, grams per hectare.
4. Calculate the amount required per tank as follows:

$$\text{Recommended application rate} \times \frac{\text{spray tank capacity (litres)}}{\text{output of spray unit (litres/ha)}} = \text{litres/tank}$$

3.5.7 Decontamination

Spraying unit contamination

It is important to adhere to the cleaning protocols outlined in the previous sections, in order to prevent spraying equipment contamination. Contamination occurs when a previous herbicide is not thoroughly cleaned from the system and is later used on a sensitive crop as a contaminant in a different herbicide.

Boom spray contamination is most commonly a problem in cereal/canola/legume rotations. It occurs when a sulfonylurea herbicide is not adequately cleaned from the spraying unit after spraying a cereal crop. If the next crop to be sprayed is a canola or legume crop, damage can occur. Chlorine (at a rate of 300 mL of 4 % chlorine solution, ie household bleach, per 100 L of water) is the best chemical for cleaning a boom spray after sulfonylurea use. To be effective, it must be agitated then left standing in the sprayer for long enough to break down the sulfonylurea molecules. When cleaning, remember to pay attention to the boom and spray lines. Nozzles and screens may need to be cleaned separately.

Contamination may also occur through other mechanisms. For example, if you have a wash out tank on your boom, it is worthwhile to check the one-way valves and ensure that your wash out water is clean. A modification kit has been made available by some boom spray manufacturers to prevent the siphoning of contaminants through one-way valves into the wash out tank.

Herbicide labels detail the appropriate method of decontamination for that product.

Chemicals other than sulfonylureas

When you have completed the spraying operation, dispose of any unused spray mix in a suitable location, well away from water catchment areas.

- Remove all nozzles and filters and drop them into a bucket of water containing a cleaning solution (see below).
- Refill the tank with water and discharge it into a sump or soakaway.
- Wash the outside of the spray unit and vehicle to remove chemical. Make sure that run-off discharges into a sump or soakaway.
- Refill the tank again and add a cleaning agent:
  oil-based chemicals - use 50 mL of liquid detergent per 100 litres of water.
  other sprays - use 100-150 g of washing soda per 100 litres of water.
  Alternatively, use household ammonia at one litre to 100 litres water.
- Agitate the solution in the tank and discharge it through the spray lines into the sump or soakaway.
- Flush the tank with clean water.
- Clean the nozzles and filters with a toothbrush.

Cleaning up after using sulfonylureas (Glean®, Ally®, Brushoff® and Logran®)

Follow the same procedure as above but use chlorine instead of household ammonia. Leave the chlorine solution in the equipment overnight before pumping out, if the next operation involves spraying vegetation that is susceptible to the sulfonylureas, repeat the procedure and pump out. Clean up the nozzles and filters in the chlorine solution before refitting them.

A commercially available product, Boom Kleen (150 g/litre potassium hydroxide, 40 g/litre available chlorine) is ideal for cleaning booms contaminated with sulphonyl urea residues.

3.5.8 Water quality for spraying herbicides

When spraying herbicides, always use the best quality water available and apply the mixed herbicide without delay. Factors which can reduce the effectiveness or change the physical compatibility are hardness, salinity, muddiness, alkalinity or acidity.

Table 6. The compatibility of different water quality factors with herbicides

Herbicide	Water Quality				
	Hard	Saline	Muddy	Alkaline	Acidic
2,4-D OR MCPA AMINE	Test	OK	OK	No	OK
2,4-D OR MCPA ESTER	Test	No	OK	OK	OK
BRODAL®	Test	OK	OK	No	Test
CHLORSULFURON	No	No	OK	OK	Better?
CORRECT®	OK	OK	OK	OK?	OK
DICAMBA AMINE	No	OK	OK	No	OK
DICLOFOP	OK	OK	OK	OK?	OK
DIURON	Test	Test	OK	Test	Test
DIURON + 2,4-D AMINE	Test	Test	OK	No	Test
DIURON + MCPA AMINE	Test	Test	OK	No	Test
FUSILADE®	OK	OK	OK	OK?	OK
GLYPHOSATE	No	OK	No	No	Better
LOGRAN®	No	No	OK	No	No
LONTREL®	Test	OK	OK	No	Test
SELECT®	OK	OK	OK	OK?	OK
SERTIN®	OK	OK	OK	OK?	OK
SIMAZINE	OK	No	OK	OK?	OK
SPRAY.SEED®	OK	OK	No	Test	OK
TARGA®	OK	OK	OK	OK?	OK
TIGREX®	No	OK?	OK	No	OK
TRIFLURALIN	OK	OK	OK	OK	OK
VERDICT®	OK	OK	OK	OK?	OK

No = Spray water not compatible with pesticide
Test = Do a jar test to determine if any reaction occurs. Various brands and formulations may react differently.
OK? = Reduced pesticide effectiveness may be experienced, especially if left in the spray vat for more than an hour or two.
OK = Pesticide normally tolerates this quality of water.
Better? = The pesticide may perform better with this water quality but it also breaks down more quickly in the spray vat. Use immediately.
Better = The pesticide may perform better with this water quality.

Evaluation of water quality

Hard: Won't lather with soap but will lather with shampoo. Total soluble salts greater than 1500 mS/m.

Saline: Tastes salty. Total soluble salts greater than 1500 mS/m.

Muddy: Difficult to see a coin in a 9 litre bucket of water.

Alkaline: pH>8. Comes from limestone or marl formations.

Acidic: pH<5. Comes from peaty soaks or swamps.

3.6 Legal aspects

3.6.1 Spray drift

Spray drift of phenoxy compounds, and the subsequent damage to susceptible crops grown close by, is a major concern in vineyard and vegetable growing districts. More recently it has become important to broadacre farming due to the wider scale sowing of lupins, canola, faba beans and peas. The knockdown herbicides Spray.Seed® and glyphosate sometimes damage crops and native vegetation by spray drift.

Small droplets have a large surface area in relation to their mass. They are therefore easily blown by wind. The higher the wind speed at the time of spraying, the more likely are droplets to be blown away from the target.

Moreover, the liquid carrier may evaporate in hot dry conditions, thus reducing the droplet size in transit from spray nozzle to target.

All spraying systems produce a range of droplet sizes, although the range produced by CDA (Controlled Droplet Applicators) is much narrower than that of conventional hydraulic nozzles. Therefore spray drift is impossible to eliminate, but it may be reduced to acceptable levels. This can be done by avoiding spraying in adverse conditions (eg during high winds and temperature inversions) and adjusting the boom spray operation.

As a rule of thumb, droplets 250µm (0.25 mm) or larger in diameter do not normally drift. So, by aiming for large droplets sizes, drift is reduced.

Smaller droplets are, however, more economical. They give better coverage for a given volume of spray and provide better penetration of foliage and attachment to leaf surfaces.

Large droplets have other disadvantages; they give an uneven cover of the target plant surface and tend to bounce off leaves. They are also less likely than smaller droplets to stick to vertical surfaces and the underside of leaves.

Misters and boom sprays produce many small droplets. Misters should never be used close to susceptible crops. Drift from boom sprays may be minimised by manipulation of the sprayer nozzles, tractor speed, boom position and volume sprayed.

Large aperture nozzles produce fewer small droplets, so choose the largest nozzles possible for the spray to be used. High pump pressure also increases the proportion of small droplets. Choose the combination of nozzles, pump pressures, volume of spray per hectare and tractor speed to give the largest nozzles at the lowest speed and highest volume, acceptable for the chemical applied to your crop.

A long droplet trajectory from nozzle to crop increases the chance of droplets evaporating. To minimise droplet travelling distance, choose wide angle flat fan nozzles angled backwards at 45° and run the boom as low as possible above crop height.

Vapour drift is a problem with certain chemicals, mainly the volatile ester formulations. The spray vaporises from the soil or plant surface after spraying and may drift many kilometres to damage susceptible crops. This mainly occurs under hot, dry conditions. It can be avoided by use of amine formulations or low volatile esters.

Weather conditions affect both droplet drift and vapour drift. Avoid hot dry conditions and windy days. The best time to spray is in cool, moist conditions in the morning or early evening, but not when the weather is calm because then temperature inversion is likely which can lead to unpredictable spread of chemical droplets. A slight breeze blowing away from the susceptible crop is ideal.

To reduce spray drift

- Avoid using volatile ester formulations (vapour drift).
- Avoid using misters.
- Fit wide angle flat fan nozzles and run the boom as low as possible above the crop height.
- Angle nozzles 45° to rear.
- Reduce boom speed. Use low pressure jets.
- Where possible spray in cool moist conditions in the morning or early evening. Avoid atmospheric temperature inversion conditions.
- Avoid spraying in hot, dry or windy conditions.
- Spray when a slight steady breeze is blowing away from susceptible crops.
- Replace worn out nozzles regularly.
- Avoid using chemicals where other weed control methods are practical and feasible.
- Choose a herbicide to which nearly all crops are tolerant.
- Consider using CDA equipment.
- Consider using drift reducing agents. eg. Lo-drift, nalcotrol.

(See WA Department of Agriculture Farmnote 37/85).

3.6.2 Legislation

Restrictions on the use of phenoxy (hormone-like) herbicides are provided by regulations under the *Aerial Spraying Control Act* and the *Agriculture & Related Resources Protection (Spraying Restrictions) Regulations, 1979*. The herbicides concerned are:

Dicamba
MCPA
MCPB
Picloram
2,4-D
2,4-DB
2,4,5-T

Triclopyr (eg. Garlon® 600 also contained in GrazonDS®) is a phenoxy herbicide but is not restricted by legislation. Nevertheless you should take similar precautions when using it.

3.6.3 Aerial Spraying Control Act, 1966

Restrictions apply in three areas of the State:

a) Within 19 kilometres of Geraldton.
b) The Swan vineyard area.
c) The Ord River irrigation area.

Within each of these areas:

a) Pilots are not permitted to undertake aerial spraying with the chemicals listed above unless:
    i. They have obtained written approval from the Director General of the Department of Agriculture, and
    ii. The spraying is carried out according to the conditions imposed at the time approval is given.
b) A pilot is not permitted to transport the listed chemicals in a spray aircraft.
c) A pilot is not permitted to fly the aircraft unless the spray tanks and spraying equipment have been cleansed of the chemicals.

3.6.4 Agriculture & Related Resources Protection (Spraying Restrictions) Regulation, 1979

Restrictions are imposed in different areas. See Table 8. These restrictions involve:

1. use of volatile esters or approved low volatiile esters or other approved phenoxy amines or salts,
2. storage of volatile esters,
3. spray contaminated vehicles and
4. permits to use approved phenoxy herbicides within a restricted area.

The use of **any kind of ester formulations** of phenoxy acid herbicides is prohibited.

The use of amine or salt formulations is permitted subject to prior written approval from the Director General of the Department of Agriculture.

The use of an approved low volatile ester is allowed.

Storage restrictions

The storage of any volatile ester of phenoxy acid is totally banned within 19 km of the Geraldton Post Office. Storage beyond 19 km but within 50 km radius of the Geraldton Post Office requires prior written approval from the Director General of the Department of Agriculture.

Contamination restrictions - vehicles and open containers

No opened container of volatile esters or equipment or vehicle contaminated with these chemicals may be stored or parked. These restrictions do not apply to a moving vehicle or to approved low volatile esters.

Permit to spray with amine or salt

The spraying of an amine or salt form of a phenoxy acid herbicide within certain areas is subject to prior written approval from the Director General of the Department of Agriculture. To obtain approval to spray, a written application must be made setting out the following information:

- approximate area to be sprayed,
- location of the area to be sprayed,
- the amine or salt form to be used,
- the method of spraying and the equipment to be used, and
- the proposed date of spraying.

Table 7. Spraying restrictions chart

PRESCRIBED AREAS AND DISTANCE FROM COMMERCIAL VINEYARDS AND TOMATO CROPS	SALT AND AMINES			LOW VOLATILE ESTERS (Approved Form)			ESTERS (Including Non-approved LV Esters)		
	Spray	Store	Transport	Spray	Store	Transport	Spray	Store	Transport
Commercial Crops									
a) 0-5 km	P	√	√	X	√	√	X	√	√
b) 5-10 km	√	√	√	√	√	√	X	√	√
Geraldton (Post Office)									
c) 0-19 km	P	√	√	X	√	√	X	P	X
d) 19-50 km	√	√	√	√	√	√	X	X	√
Kununurra									
e) 0-10 km	P	√	√	X	√	√	X	X	X
f) 10-15 km	√	√	√	√	√	√	X	X	√
Swan Valley									
g)	P	√	√	√	√	√	X	√	X

P = Permit required X = Not Permitted √ = OK to spray, store or transport

Elsewhere in the State no restrictions apply. For exact definitions refer to the Act and its Regulations.

3.7 Zadoks decimal growth scale

The Zadoks scale is a 10-part scale describing crop growth stages. It is useful for accurately describing growth stages of crops and is frequently used to pinpoint optimum application times for particular herbicides.

Only stage 1 (leaf production) and stage 2 (tillering) are described here.

How the scale operates

- Each scale comprises two numerals, the first indicating growth stage ie. 1 (leaf production) or 2 (tillering) and the second, the numbers of plant parts (leaves or tillers respectively). For example, Z13 indicates a plant with three leaves.
- As the plant grows, tillers emerge. The numeral 2, following an oblique stroke, identifies the tillering stage. It too is paired, the second numeral of the pair giving the number of tillers. For example, a five leaf plant with three tillers would be Z 15/23.

Using the scale

Step 1. Growth stages will vary slightly within every paddock, so select a representative plant or plants.

Step 2. If the plant is a seedling with only a single stem, count the leaves. If it is more advanced with tillers present, identify the main stem, and count its leaves.

Step 3. Count the tillers, but do not include the main stem as a tiller.

An account and illustrations of using the Zadok scale are given in Bulletin 4243 "Management of agricultural weeds in Western Australia", page 105.

3.8 Aquatic weeds

3.8.1 Aquatic weeds in farm dams

Rising temperatures and falling water levels over summer lead to a spate of enquiries concerning control of aquatic weeds in farm dams.

Although farmers are often concerned about whether the weed is declared or is a potential problem, most water weeds sent for identification are native plants that present few problems.

Most commonly found species belong to the pond weed family - Potamogetonaceae. Of these, floating pond weed (*Potamogeton tricarinatus*), and blunt pond weed (*Potamogeton ochreatus*) are the most common. Duckweed (*Lemna* spp.), red azolla (*Azolla* spp.) and common water milfoil (*Myriophyllum propinquum*) are also widely distributed, but stonewort (*Chara* spp.), and sea tassel (*Ruppia maritima*) are also occasionally reported.

Declared aquatic weeds found in WA include water hyacinth (*Eichornia crassipes*), salvinia (*Salvinia molesta*), parrot’s feather (*Myriophyllum aquaticum*), hydrocotyle (*Hydrocotyle ranunculoides*) and leafy elodea (*Egeria densa*). These are not common to farm dams.

Before deciding to control weeds in dams, remember these weeds may provide food and shelter for bird life and fish.

Aquatic weeds can be categorised as follows:

Emergent weeds - weeds that have stems and leaves protruding above the water surface or grow where the watertable is near ground level. Examples of these are cumbungi, rushes, sedges, paspalum, water couchgrass, arum lily.

Free floating - these weeds are not attached to the soil, but they may have root systems. Examples are salvinia, water lettuce and water hyacinth (in deep water).

Floating leaf - these water weeds are rooted to the soil but have long stems that stretch to the water surface and floating leaves. Examples are water lilies, nardoo and hydrocotyl.

Submerged - these water weeds are mostly completely submerged in shallow water up to 3-4 metres depth. They are rooted to the soil with thread-like, ribbon-like, broad or finely dissected leaves. Examples are pond weeds (*Potamogeton* spp.) and elodea.

3.8.2 Aquatic weed control

Aquatic weeds can be controlled by mechanical and chemical means.

Mechanical control such as cutting, mowing, dredging, drying, chaining, etc., may be necessary and effective in small areas, particularly where chemical control is not appropriate. Mechanical control is generally expensive, and short-lived. It can even help spread of weeds due to propagation from root or stem fragments.

Chemical control always needs careful thought before starting to spray.

Check this list before starting.

a) Is the weed correctly identified?
b) What chemical is appropriate? (Given that there is a choice).
c) Will the chemical harm desirable plants or fish and other aquatic life?
d) Is the water to be used for irrigation, stock, etc.?
e) Is the water still or moving - can it be drained?

Other matters to be taken into account are the size of the infestation and the method of applying the herbicide effectively and uniformly in the correct concentration.

Chemical control of aquatic weeds must be undertaken with considerable care and adequate planning.

Herbicides for aquatic weed control

Read the Water and Rivers Commission policy regarding use of pesticides in catchment areas (available on the Water and Rivers Commission web site at http://www.wrc.wa.gov.au/protect/policy/pesticide%20policy_final.pdf):

> Anon. (2000). *Pesticide use in Public Drinking Water Source Areas*, Water and Rivers Commission, Statewide Policy No. 2.

Also read the Department of Health circular on the use of herbicides in water catchment areas (available on the Department of Health web site at http://www.public.health.wa.gov.au/environ/applied/PSC88.DOC):

> Anon. (1993). *Use of Herbicides in Water Catchment Areas*. Department of Health, Circular No.: PSC 88.

The pesticide Advisory Committee is currently reviewing PSC 88 with the view of including ground water as well as surface catchment water. The new format is proposing to evaluate each submission to apply pesticides (not only covered by herbicides as covered in PSC 88) and make a decision based on the type of herbicide and its use pattern.

Emergent weeds - Glyphosate, where recommended on the label for aquatic areas, at the stated label rates is now the preferred herbicide for most emergent aquatic weeds. Many glyphosate products now have 'frog friendly' surfactants and are registered for aquatic weeds. Reglone® and dichlobenil are also currently approved for use in Western Australia.

Before applying any other herbicide to rivers or drainage areas check with the Department of Health.

Free floating and floating leaf weeds - A range of chemicals can be used on these aquatic weeds. The choice would depend not only on the weed species but also the situation in which the weed is being sprayed. Reglone® (diquat), 2,4-D, glyphosate (when weeds are actively growing and not liable to submergence) and Casoron® (dichlobenil) all have their place.

Submerged weeds - These are perhaps the hardest aquatic weeds to kill because chemicals used need to be maintained at a sufficiently high concentration in the water for enough time to kill the weeds. Water volumes need to be determined reasonably accurately and the chemicals must be applied uniformly to achieve the desired results. Herbicides used for submerged weed control are Reglone®, Casoron® (granulated), and Magnacide® (acrolein - toxic to fish and licensed operator required).

Note: Large masses of aquatic weed killed by herbicide will rot. This depletes water oxygen levels and will possibly lead to the formation of an algal bloom.

Read the label and observe the withholding period before using water for stock or irrigation.

Many herbicides are registered for use in other states of Australia, but not in Western Australia. To use these, a special permit is required from the National Registration Authority.

3.9 Herbicide products available

A wide range of herbicide products are available for use in Western Australia. For full details of herbicides available, contact your stock agent or consult the latest "Planfarm Herbicide Guide", which has details of farm chemicals and their producers. For a copy of the "Planfarm Herbicide Guide", contact Planfarm (4 Clive St West Perth, WA, 6005. ph: 9322 7244, fax: 9321 4159, web site: http://www.planfarm.com.au).

Additional information on herbicides is available from the National Registration Authority web site: http://www.nra.gov.au.

Commercial CDs of registered products are available:

1. Infopest (e-mail infopest@dpi.qld.gov.au with enquiries or look at the DPI web site: http://www.dpi.qld.gov.au/infopest/), and
2. inFINDer (e-mail wilson.michelle@saugov.sa.gov.au with enquiries or look at the PIRSA web site: http://www.pir.sa.gov.au/pages/sus_res/chemicals/advert.htm).

3.10 Surfactants, Wetting Agents, Anti-Drift Thickeners and Petroleum Oils

The word "surfactant" is a contraction of the words "surface active agent", and includes both emulsifiers and wetting agents.

Emulsifiers are usually added to the product by the manufacturer to allow the herbicide to mix with water.

Wetting agents are added to many spray mixtures, particularly when the plant to be sprayed has leaves with a waxy or hairy surface, or is otherwise difficult to wet. In some circumstances, the use of a wetting agent will cause too much of the spray material to run off the foliage, resulting in reduced uptake of the chemical. Therefore wetting agents should be used only when recommended, and then at no higher than the recommended rate.

NB. Surfactants (wetting agents) should never be used for selective weed control unless specified in the label recommendations.

Crop oils can act as carriers for herbicides, anti-evaporants and aid entry of the herbicide into the plant.

Drift control agents (or thickeners) increase droplet size, and therefore minimise the formation of small droplets which may cause a drift problem.

4 How to use the Declared Plant Control Tables

Recommendations

The following notes should be read in conjunction with the recommendations that follow:

Weed: These are declared plants listed in order of their common name. For scientific names, see the Gazetted Declared Plants List at the Department of Agriculture web site: http://www.agric.wa.gov.au.

A = Annual

P = Perennial

Herbicide: The recommendation gives the chemical name of each herbicide. Please check the herbicide label at the time of purchase for the currency of these recommendations. Further information on herbicide trade names, active ingredients and chemical groupings can be obtained from the National Registration Authority's "PUBCRIS" product database at http://www.nra.gov.au/pubcris/subpage_pubcris.shtml.

Knapsack dilution: this is based on an application rate of 1000 litres per hectare. If you intend to apply a different volume of the product, the rate would have to be adjusted accordingly. For example: a recommended dilution of 1:800 for 1000 litres per hectare volume output (12.5 mL per 10 L) would have to be changed to 1:1600 for 2000 litres per hectare output (6.25 mL per 10 L). Calibration is essential. The table shows the amount of herbicide to be added per 10 litres of knapsack volume.

Rate per hectare: The recommendation is given as the rate of herbicide product per hectare, using low-volume spraying equipment. The rates given in this column can also be used as a basis for applying the herbicide through a mister where appropriate.

General: In line with current practice, the rates of application of the recommended herbicides are given on the assumption that a product is used containing the shown active ingredient of the herbicide, expressed in grams per kilogram or litre (g/kg or g/L).

N.R. = NOT RECOMMENDED.

1. Dilutions are for knapsack only, not power mister.

In many instances, the recommendations for the addition of wetting agents or oil additives is based on limited trial data. Certainly rate recommendations have not been accurately defined. In non-selective situations, the addition of wetting agents or oils in unlikely to result in adverse effects so their inclusion is recommended even if their value is in doubt. Since wetting agents vary considerably in their active ingredient content, rates indicated in these recommendations are intended as a guide only. Always refer to the herbicide label for recommendations on the use of surfactants. Use non-ionic surfactants unless recommendations state otherwise.