The economics of weed control in horticultural crops

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SUMMARY

Weed control is an essential aspect of the production of all horticultural crops and except where cultivation is needed for other purposes, such as covering potato tubers, herbicides are being used on a greater proportion of crops. Selective materials are used in annual row crops and contact desiccants and soil sterilants in trees and vines. The greatest problem in tree and vine crops is the establishment of resistant perennial weed species.

Experiments have in many cases established that chemical weed control will give increased yields apparently due to the reduction of root damage. Herbicides can be applied with less labour than that required for mechanical control measures and they generally give more complete control. Herbicides are particularly effective in the establishment of young direct seeded vegetable crops and young orchards.

Overall the cost of weed control measures in intensive crop ranges from about 1 to 10% of the total variable costs. In broad area crops such as peas and in young orchards and vineyards the weed control is a major cost factor.

INTRODUCTION

There are some 60 to 70 horticultural crops grown in Australia including temperate tree fruits, sub-tropical fruits, grapes, berry fruit, vegetables, hops and tobacco. In the year ending 30 June 1976, the total value of these crops was estimated by the Australian Bureau of Statistics (1977a and b) as being $676 million or 11.3% of the total gross value of all agricultural commodities. The values of the main horticultural crops over the period 1971/72 to 1975/76 are shown in Table 1.

As pointed out by Mears and Green (1968) the losses caused by weeds in horticultural crops are probably of the same order as in other crops but because of their high value per unit area the monetary losses caused by weeds are also high.

Chemical weed control methods have been generally adopted for most vegetable and some fruit crops, especially citrus, bananas and pineapples.

Plastic mulches are in general use for strawberry production to conserve moisture, suppress weeds and improve plant growth and fruit quality.

Herbicides are now widely used in tobacco growing.

Table 1. Gross value of horticultural crops grown in Australia from 1971/72 to 1975/76 ($'000)

	1971/72	1972/73	1973/74	1974/75	1975/76
	Gross Value of Fruit and Grapes				
Fruit -					
Orchard -					
Citrus -					
Oranges	30,423	33,556	33,661	43,301	46,137
Lemons and limes	4,107	4,780	4,635	5,434	5,186
Mandarins	4,037	4,674	5,413	6,736	7,046
Other	2,797	2,694	2,800	2,757	3,015
Pome -					
Apples	50,310	63,483	63,733	73,617	67,552
Pears	19,448	23,942	24,938	26,199	11,041
Stone -					
Apricots	7,764	9,170	9,141	9,032	8,945
Cherries	5,884	5,718	7,495	10,277	8,535
Peaches	15,876	17,678	14,494	24,199	17,034
Plums and prunes	5,228	5,974	7,031	8,463	9,340
Other orchard fruit (incl. olives & nuts)	3,524	4,801	4,854	5,124	5,348
Small & berry fruit -					
Strawberries	2,861	3,740	3,634	4,592	4,471
Other	1,213	1,264	1,103	1,522	928
Other fruit -					
Bananas	20,958	28,217	21,878	31,323	40,568
Pineapples	9,629	12,197	11,028	11,914	14,182
Other	2,128	1,626	1,418	2,050	2,889
Total fruit (excl. grapes)	186,181	223,523	217,258	266,541	252,229
Grapes -					
Table	7,153	6,830	8,849	9,170	9,396
Wine	25,080	27,196	33,472	55,209	53,403
Dried	34,070	30,846	40,883	37,011	34,873
Total grapes	66,306	64,871	83,205	101,391	97,668
Vegetables	158,379	181,420	239,685	256,870	275,089
Tobacco - dried leaf	40,995	37,896	42,396	49,012	51,153
Total Hort. Crops	451,861	507,710	552,844	673,814	676,139

Vegetable crops

Weeds can be a significant factor in determining the yield of many vegetable crops, they compete for moisture, nutrients and light, harbour pests and diseases, reduce air circulation and contaminate produce.

With the development of mechanical harvesting techniques weeds have become more significant in crops such as peas, beans, tomatoes and potatoes. Blackberry nightshade (*Solanum nigrum* L. sens. lat.) berries are a real problem in processed peas, thornapple (*Datura stramonium* L.) will break picking reels on bean harvesters, while wireweed (*Polygonum aviculare*), couch grass (*Cynodon dactylon*) and Wimmera ryegrass (*Lolium rigidum* Gaud.) will choke pea viners and tomato, potato and onion harvesters.

Direct seeded crops such as carrots, onions, parsnips and tomatoes are particularly susceptible to weed competition when seedlings are very small.

Good cultural practices have always been the basis of effective weed control programs with timely cultivations to prevent weeds seeding and strategic rotations including periods of fallow. Mechanical inter-row cultivation developed in the 1940s with the introduction of tractor-mounted cultivators.

About the same time kerosene mixtures were introduced for weed control in carrots and a few years later dinoseb became available for weed control in peas. The introduction of chlorpropham in the 1950s revolutionized the growing of onions in southern Australia. Selective herbicides are now available for all vegetable crops with the notable exception of members of the family Cucurbitaceae.

I have estimated that weed control measures directly associated with growing vegetable crops, including inter-row cultivation, hand-weeding and herbicide application, cost Australian growers about $ 11 million each year which is 3.7% of the total gross value of vegetable crops grown in Australia in 1975/76.

The estimated adoption of chemical weed control in various vegetable crops is set out in Table 2. It is emphasized that these figures are estimates only and are not based on specific surveys; these have been weighted according to the area of the particular crop in each state.

Potato growers have generally been slow to adopt the use of herbicides to control weeds in the growing crop except in the earlier districts where metribuzin, in particular, has found a place. In most mid-season and late districts, growers keep plants well hilled to prevent tubers becoming exposed, this also keeps most weeds under control. Herbicides are also used to knock down growth to facilitate harvesting of late crops.

While herbicides have in most cases reduced the cost of weed control many growers have to carry out some mechanical and hand weeding to control resistant weeds or compensate for inefficient chemical control of susceptible weeds.

Table 2. Use of herbicides on vegetable crops in Australia

Crop	Area 1975/76 (ha)	Estimated proportion of crop treated with herbicide* (%)
Asparagus	2,289	52
Beans	7,623	29
Beetroot	805	69
Cabbage	2,724	65
Carrots	3,335	96
Cauliflower	2,591	63
Celery	439	100
Cucurbits	12,665	5
Lettuce	2,289	72
Onions	4,015	99
Peas	18,978	94
Potatoes	33,810	5
Sweet corn	3,100	80
Tomatoes	7,917	60

*Source: Estimates by officers of State Departments of Agriculture and Primary Industry.

Table 3 shows my estimates of the costs of mechanical and chemical control measures for the main vegetable crops. To arrive at these costs herbicide recommendations for vegetable crops in Victoria (Anonymous, 1976) and the retail cost of herbicides from a Melbourne supplier were used. Labour was costed at $3.50 an hour and tractor operations at $2.50 an hour. Clearly the cost of both mechanical and chemical control measures will vary considerably according to the weeds present, time of year, soil type, weather conditions and timeliness of operations.

In many cases these comparative costs do not do justice to chemical methods of weed control. Many shallow rooted crops are quite severely damaged by cultivation too close to the plants. The advantage of chemical over mechanical weed control is well illustrated in Table 4 with data from our own trials (Morgans, 1978, personal communication).

Although the cost of mechanical and chemical control measures can be quite considerable, as illustrated in Table 3, the total cost of all weed control measures are but a relatively small proportion of total variable costs as illustrated in the examples in Table 5.

Pome fruit

The traditional system of soil management in apple orchards in southern Victoria was to "plough on" in the autumn and "plough off" in the spring to leave a relatively flat clean cultivated area between the trees. Cultivation not only damaged tree butts and surface roots, but also damaged soil structure. Clean cultivation also presented problems in the winter; soil would become very wet between the tree lines and often it was impossible to get a spray machine between the trees (Kenez, 1970).

Table 3. Estimated cost of chemical and mechanical weed control per ha of crop

Crop	Herbicide (1)	Herbicide and mechanical (2)	Mechanical only (3)
	$ per ha	$ per ha	$ per ha
Asparagus	46	100	120
Beans	20	92	120
Beet	90	208	248
Cabbage	38	115	232
Carrots	38	65	100
Cauliflower	38	96	230
Celery	20	32	-
Cucurbits	-	-	158
Lettuce	188	230	370
Onions	264	324	-
Peas	23	29	-
Potatoes	55	150	60
Sweet corn	20	41	60
Tomatoes	76	183	335

Notes: (1) Herbicide cost only. Melbourne retail.
(2) Includes cost of herbicide and application.
(3) Labour costed at $3.50 per hr.
Tractor at $2.50 per hr.

Table 4. The effect of mechanical and chemical weed control on crop yields in Victoria

Crop	Chemical control t/ha	Mechanical control t/ha	Difference %
Beans	6.09	4.25	+ 43
Celery	43.9	37.3	+ 18
Onions	37.6	27.6	+ 36
Spinach	24.7	20.5	+ 20

Table 5. Cost of weed control measures relative to the total variable costs of growing a number of vegetable crops in Victoria and New South Wales

Crop	Locality	Proportion of cost (%)	Remarks*
Carrots	Cranbourne	2.6	c,h,hw
	Monbulk	1.4	c,h
	Singleton	4.5	c,h
	Cranbourne	10.7	c,h,hw
Cauliflower	Werribee	11.8	c,h
Celery	Clyde	1.1	c,h
	Clyde	6.0	c
Beans (processing)	East Gippsland	9.8	c,h
	Grafton	19.7	c,h
(fresh)	Nambucca	5.2	h
Lettuce	Hawkesbury	21.3	c,h,hw
	Cranbourne	1.5 - 8.4	c,h
Melons	M.I.A.	2.2	c,hw
Onions	Colac	14.0	c,h,hw
Potatoes	Guyra	2.5	c
	Cranbourne	4.2	c,h
Peas	Colac	22	h

* c = cultivation; h = herbicide; hw = hand weeding.

Volunteer weeds or sown cover crops were found not only to dry out the soil, but also to improve the soil structure. Heavy permanent pasture sods, particularly those containing vigorous clover species, suppressed other weed growth. Special mowers were developed to cut right up to the tree butt. This was a relatively slow operation so herbicides were introduced to kill weeds in an area of 1 to 2 m^2 around the tree or in a strip 1 to 2 m wide along the entire tree line. The pasture sod between the tree lines could be kept trimmed with mowers travelling at 6 km/hr instead of 2 or 3 km/hr.

The main soil management systems used in pome fruits are:

(a) Clean cultivation from tree line to tree line.

(b) Clean cultivation to within half a metre of the tree line and a metre wide strip along the tree line sprayed with herbicide.

(c) Permanent sod with a 1 to 2 m^2 around the tree or a 1 to 2 m wide strip along the tree line sprayed with herbicide. Strip spraying is generally used in established orchards.

(d) Plastic, straw or sawdust mulches have been tried, but are now seldom used.

The main problem in orchards with chemical weed control is the development of a population of herbicide resistant perennial weeds such as couch grass (*Cynodon dactylon*), paspalum (*Paspalum dilatatum*), dock (*Rumex* spp.) and sorrel (*Rumex acetosella*).

The benefits of herbicide treatments are seen particularly in young trees where root development, and subsequent top development, is faster, leading to trees bearing sooner than those under cultivation only.

The total labour cost in establishing an apple orchard over a 5 year period is estimated at $750 per ha. About a third of the labour is directly associated with weed control measures - mowing, spraying and hand weeding.

Comparative costs of total weed control with herbicides and mown sod culture are illustrated from a study at Batlow in 1975 (Johnson, 1977, personal communication); labour and herbicide costs are given at current rates (Table 6).

Table 6. Comparison of cost of permanent sod and herbicide under apple trees at Batlow, N.S.W.

	Sod management	Herbicide management
	$ per ha	$ per ha
Equipment*	49.24	2.95
Materials (herbicide)	nil	31.56
Labour	9.99	3.51
Total cost	59.23	38.02

* Includes depreciation, interest and operating.

Table 7 lists some eight herbicides for use on apples. The costing is based on spraying a 2 m strip along the tree line (Anonymous, 1977a).

In southern districts of Victoria almost all growers now use some form of sod management with a sprayed strip along the tree line, whilst in the Goulburn Valley most growers cultviate between the tree row, with only about 20% using a herbicide in the tree line. About 65% of pome fruit growers in N.S.W. use herbicides annually.

Stone fruits

Most stone fruit growers cultivate between trees rather than maintain a pasture sward. In the winter months, volunteer weeds are allowed to grow, or a green manure crop is sown. In frost prone areas dense pasture, or weed swards, or green manure crops will increase the severity of frosts in the winter months.

Observations in southern Victoria indicate that peaches are generally healthier under cultivation than with permanent sod.

Table 7. Cost of spraying a hectare of orchard with herbicide in strips 2 m wide along the tree line with 270 trees/ha (6 m x 6 m)

Herbicide	Rate of product per ha sprayed	Cost per ha of orchard sprayed ($)
1. Simazine 80% w/w	2.28 kg	7.28
2. 2,2-DPA 74% w/w	8.0 kg	8.53
3. Paraquat 20% w/v	2.5 ℓ	8.61
4. Diquat 20% w/v	2.5 ℓ	8.93
5. Diuron 80% w/w	4.5 kg	9.00
6. Amitrole 25% w/v	9.2 ℓ	10.03
7. Terbacil 80% w/w	2.5 kg	31.34
8. Glyphosate 36% w/v	6.0 ℓ	34.55

In Victoria and New South Wales it is estimated that about 20% of growers use herbicides either as sprayed squares around trees or in strips along the tree line (Black, 1978, personal communication). Costs of spraying are similar to those outlined for pome fruit.

Citrus fruit

Herbicide usage on citrus crops has increased considerably since pre-emergent materials were introduced early in the 1960s. Growers now either spray the entire surface or maintain weed-free strips along the tree line leaving a sod, green manure crop, volunteer weeds or a cultivated area between the sprayed areas. It is estimated that 70 to 85% of growers either completely spray or strip spray citrus groves (Duncan, Black, 1978, personal communication).

In the Murrumbidgee Irrigation Area (M.I.A.) Coomer (1977) found that over a 5 year period the total cost of cultivation was $ 365 compared with $422 for herbicides which is equivalent to an annual cost of $73 and $84 per ha respectively. Over 16 orchards in the M.I.A. the cost of weed control measures represented 5.9% of the total variable costs.

Herbicides are a major proportion of establishment costs in citrus. Hannah (1978) reports that in Queensland the current cost of herbicides is about $180 per ha which is 30% of the total variable costs in the second year, but declines to about 4% as the grove ages and other imputs increase.

In the experiment carried out by C.S.I.R.O. at Griffith, Carey (1972) recorded consistently higher yields in plots which had zero tillage/herbicide treatments for both Navels (124%) and Valencias (117%) compared with plots which had tillage and sod culture for more than 20 years. Growers in the M.I.A. generally claim 10 to 20% yield increases for herbicide treatments over cultivation.

Grape vines

Weeds are generally controlled in vineyards by cultivation, but about 20% of growers in Victoria and New South Wales use under-vine herbicides. Chemicals used include paraquat, diquat, 2,2-DPA, diuron and simazine.

Herbicide treatments reduce root damage, are less time consuming and generally give better and cheaper weed control than cultivation. Herbicides are almost essential where trickle irrigation systems are used. The main problem with the use of herbicides in vineyards, as in orchards, has been the build-up of resistant perennial species.

A comparison of the cost of undervine weed control with herbicides and with cultivation is shown in Table 8.

Table 8. Comparison of costs of undervine weed control

Item	Chemical weed control	Cultivation
Labour (time)	4 hours	12 hours
(cost $3.50/hr)	$14	$42
Tractor ($2.50/hr)	$10	$30
Herbicide:		
Diuron 2.4 kg/ha	$27	-
Amitrole	$17	-
Total cost	$68	$72

In subsequent years the rate of herbicide applied can be reduced to half bringing the total cost of the herbicide treatment to $46 per ha.

The total cost of weed control, mechanical, chemical, or a combination of both, is about 7.5% of the total cost of growing the crop (including depreciation and maintenance of plant).

Recently Godden (1977) in an experiment at Avoca, Victoria, has lifted the yield of Cabernet Savignon grapes by 250% using black polyethylene mulch to establish vines instead of herbicide treatments. Both mulch and herbicide treatments were irrigated by a trickle system.

Bananas

Weeds left uncontrolled can reduce the yield of a banana plantation to half. However, growers are required to keep plantations weed-free to enable inspection for bunchy top and banana weevil borer.

Weeds are controlled solely by the use of herbicides. Eighty percent of the herbicide used is paraquat; other materials include arsenic pentoxide or trioxide, 2,2-DPA, amitrole, atrazine and more recently glyphosate.

The cost of herbicide treatments range from $23 to $70 per ha per year which is 4 to 5% of the total cost of growing bananas, excluding harvesting (Chalker, 1978, personal communication).

Strawberries

Black polyethylene mulch is now used almost universally for strawberry production. Diquat and paraquat are used to clean uncovered areas between beds. Chlorthal is used on unmulched beds. The cost of polyethylene mulching is $420 per ha for materials and $180 for laying by contractor.

Bramble berries

Chlorthiamid granules are used to suppress weeds beneath blueberries, loganberries, youngberries and others.

Nuts

One of the main objectives of weed control in nut groves is to provide a clean surface from which the nuts can be picked after being shaken from the tree. Pasture is grown under trees and slashed to provide a good picking surface. Chemical weed control is also used to provide a hard surface for mechanical sweeping of nuts from beneath trees although this system is not well developed in Australia.

Pineapple

Complete weed control with herbicides is the general practice in pineapple production. Diuron, bromacil and ametryne are the most commonly used herbicides. The normal schedule is 4 to 8 kg/ha of bromacil or diuron at planting or a mixture of 2 to 4 kg of each material followed 6 months later by a 'top-up' spray at about half the initial rate.

Ametryne is used as a knockdown spray usually at 2 ℓ/ha to control broadleaf weeds which come through the diuron or bromacil. Some spot chipping is still done.

A typical crop cycle in pineapples consists of two harvests over three and a half years. Total variable costs per ha are estimated at $3,410 of which weed control costs amount to 5%. This may be broken up into tractor use, 2%; chemicals 2%; and labour, 1% (Cull, 1978, personal communication).

Avocado, Custard apple and Macadamia

These tree crops are grown with an inter-row grass sward which is slashed and a herbicide sprayed strip along the tree line. Spraying is done with hand lances from a power sprayer using paraquat.

Avocados approach commercial production in about 4 years and at this stage 16% of their variable costs are associated with chemical weed control - 4.4% for tractor, 4.8% for labour and 7% for chemicals. The total variable cost at 4 years for avocado is $438 per ha (Cull, 1978, personal communication).

Macadamias and custard apples do not reach full commercial production until 8 years old and variable costs are $1,016 and $1,542 respectively. Again about 16% of the total variable costs are expended on chemical weed control (Cull, 1978, personal communication).

Tobacoo

The control of weeds in tobacco is essentially similar to a number of vegetable crops. Inter-row cultivation and hand hoeing have been the basic control measures and even though 70% of growers now use nitralin or benfluralin as pre-plant herbicides, 90% of growers carry out some hoeing. With herbicides, about 9 hours labour per ha is required for hoeing, while with no pre-emergent herbicide an average of 20 hours hand labour is necessary. Growers carry out 3 to 6 inter-row cultivations a year (Worden, 1978, personal communication).

Cost surveys in Victoria show that the cost of mechanical and chemical weed control is $460 per ha which represents about 12% of the total variable costs. The cost of herbicides is $20 to $50 per ha.

Hops

Mechanical weed control methods are generally used in hop gardens in Victoria, but herbicides are generally used in Tasmania.

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