# WEED MANAGEMENT STRATEGIES IN VEGETABLE PRODUCTION AND THEIR AGRONOMIC, ENVIRONMENTAL AND ECONOMIC IMPLICATIONS

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**Summary** Weed management in vegetable production reflects practices available, e.g. herbicide options, mechanical cultivation, labour availability, and crop rotation choices. Strategies depend on time scales over which we view weed management; extremes would be a short-term, single crop strategy versus a weed eradication program. At Gatton Research Station, we are conducting experiments comparing agronomic, environmental and economic implications of four weed management philosophies in production of vegetables such as potatoes, onions, leafy vegetables and brassicas.

In a lettuce experiment, an *eradication* strategy comprised 1.32 kg $ha^{-1}$ of pendimethalin one day before transplanting, with a single hand-weeding one week before harvesting (to prevent weed seed-set). Compared with a *short-term* strategy (with 1.00 kg $ha^{-1}$ pendimethalin and no final hand-weeding), the *eradication* treatment only cost an extra $A35 $ha^{-1}$. I believe this minimal cost would be recouped through easier weed management during ensuing years.

In a cabbage experiment, pre-emergence spraying of oxyfluorfen herbicide (not yet registered) gave excellent control of bittercress (*Coronopus didymus*), fat hen (*Chenopodium album*) and small-flowered mallow (*Malva parviflora*), with no crop damage. We compared this treatment with spraying metolachlor, or pendimethalin/propachlor combinations at registered rates. Metolachlor gave better control of bittercress than pendimethalin/propachlor mixtures, which in turn killed more fat hen and small-flowered mallow. Oxyfluorfen sprayed before transplanting was the best herbicide option, due to least cost, greatest yields, most effective weed control and least seedbank contribution. Registration of in brassicas should be a priority.

## INTRODUCTION

Simple 'quick-fix' solutions to weed control, whilst they may have worked to some degree in the past, may no longer be appropriate nor acceptable to society. The focus of weed management must change to a more integrated approach (Putnam 1990, Swanton and Weise 1992). High herbicide costs, crop phytotoxicity, rotation restrictions, application inflexibility, herbicide resistance (Schroeder *et al.* 1993), and the requirement for expensive hand-weeding are issues. Approaches to integrate various weed control practices, in conjunction with knowledge of target weed biologies, are sought.

In this paper I report initial studies on experiments establishing long-term weed management plots. These experiments are investigating the impacts of weed management strategies on weed populations, production practices and outcomes, and overall system economics.

## MATERIALS AND METHODS

Two experimental sites each containing 16 long-term plots were laid out on black earth soils at the QDPI Gatton Research Station in south-east Queensland. Individual plot dimensions were 125 $m^2$. The 16 plots comprised four weed management strategies, replicated four times in blocks. These weed management strategies were:

- Short-term practices determined on single-crop economic considerations, implementing the most cost-effective weed management practice for the individual crop and ignoring the consequences of allowing seed-set for following crops. This is a strategy commonly adopted by vegetable producers.
- Long-term practices aimed at long-term weed suppression, using measures less economic in the short term, but aimed at reducing weed seedbanks, and thus the long-term costs of weed control. Often involves more expensive herbicides, post-emergence spraying, or more cultivation and hand-weeding. It may mean selection of different rotations and more concern with weed management in cover crops.
- Eradication simply requires prevention of weed seed-set by the most cost-effective method; generally combining herbicides, cultivation and hand-weeding, conducted at all times during the year.
- Future practices using unproven cultural methods or unregistered herbicides, that have potential to improve our weed management options.

In all the experiments reported here, I applied the herbicides with a motorized knapsack sprayer. The 1.5 m wide hand-held boom had 110° flat-fan nozzles spaced 0.30 m apart. It was operated at 200 kPa and sprayed 250 L $ha^{-1}$.

In mid-August 1995, a lettuce experiment was implemented on one site, and a cabbage experiment on another. Apart from the weed management treatments, other agronomic inputs, including nutrition, pest and disease control, plant spacings, etc., were as per standard commercial practice. Crops were transplanted into 1.5 m wide beds, with three rows of lettuce or two rows of cabbage per bed. Intra-row spacings were 0.33 m for lettuce or 0.67 m for cabbage.

**Lettuce** Lettuce seedlings were transplanted into beds on 16 August 1995. The herbicides pendimethalin (Stomp™) and propachlor (Ramrod®) were used in this experiment. Pendimethalin is registered for use in lettuce; whereas propachlor is not. Short and long-term strategies involved spraying 1.00 kg $ha^{-1}$ of pendimethalin one day before transplanting. Because of low weed densities, additional cultivation was not required in the long-term strategy. In the eradication treatment, pendimethalin was sprayed at 1.32 kg $ha^{-1}$ one day before transplanting, with a single hand-weeding 55 days after planting (DAP) to remove flowering weeds. In the future strategy, 1.00 kg $ha^{-1}$ of pendimethalin was applied before transplanting, with 2.16 kg $ha^{-1}$ of propachlor sprayed over the lettuce five days after transplanting.

Heights of 28 randomly selected lettuces were measured in each plot 17 DAP. Lettuces were harvested 58 DAP. The numbers of marketable lettuces in each plot were counted, then samples of 168 lettuces per plot were cut and weighed. After harvesting was completed, flowering or older weeds were cut at ground level, separated into species, counted and weighed.

**Cabbage** Cabbage seedlings were transplanted on 17 August 1995. Metolachlor (Dual®), pendimethalin, propachlor and oxyfluorfen (Goal®) herbicides were used in the experiment. Of these, only oxyfluorfen is not yet registered in cabbage, despite use in brassicas overseas.

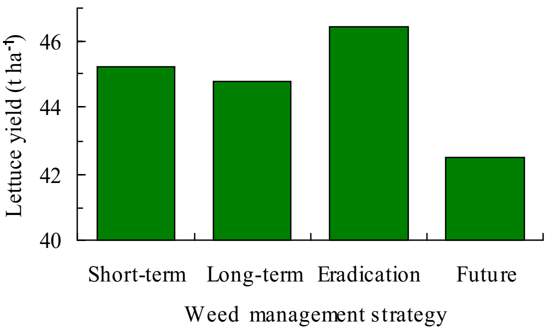


**Figure 1.** Weed management strategies have minimal impact on yields of marketable lettuce.

In the short-term treatment, 2.52 kg $ha^{-1}$ of metolachlor was sprayed over the cabbages one day after transplanting. Pendimethalin was applied one day before transplanting at 0.67 kg $ha^{-1}$ in the long-term treatment and 1.00 kg $ha^{-1}$ in the eradication treatment. One day after transplanting, propachlor was sprayed over cabbages at 3.36 kg $ha^{-1}$ and 4.32 kg $ha^{-1}$ for the two respective strategies. The herbicide component of the future strategy comprised oxyfluorfen sprayed at 0.36 kg $ha^{-1}$ one day before transplanting. All treatments were hand-weeded 62 DAP.

Heights of 28 randomly selected cabbages were measured in each plot 15 DAP, with widths recorded 39 DAP. All cabbages were harvested 104 DAP. The total numbers of marketable cabbages in each plot were counted, then samples of 70 cabbages per plot were cut and weighed. After the harvest was completed, weeds capable of setting seed within the next week were cut at ground level, separated into species, counted and weighed. During the hand-weeding 62 DAP, numbers of broadleaf weeds, excluding burr medic (*Medicago polymorhpha*) were counted before chipping. The time taken to hand-weed each plot was recorded.

## RESULTS AND DISCUSSION

**Lettuce** Lettuce from areas treated with 1.32 kg $ha^{-1}$ of pendimethalin, or sprayed with 2.16 kg $ha^{-1}$ of propachlor, were significantly shorter (15%) than those where only 1.00 kg $ha^{-1}$ of pendimethalin was applied.

Averaged over all weed management strategies, about 80% of transplanted lettuce produced marketable heads. Lettuces in the eradication strategy completely recovered from any initial stunting, to provide highest yields in the experiment. There was a slight trend for marginally lower production of lettuces sprayed with propachlor (Figure 1). Any differences in yields between weed management treatments were associated with delayed maturity, and hence slightly smaller heads. Delays in maturity are symptomatic of propachlor injury in lettuce. Whilst the same number of marketable heads would have been available from all four strategies, harvesting from the future treatment may have been spread over a slightly greater period.

Weed species consistently represented throughout the experimental area included London rocket (*Sisymbrium irio*), green amaranth (*Amaranthus viridus*), fat hen (*Chenopodium album*) and bittercress (*Coronopus didymus*). When eradication treatments were hand-weeded 55 DAP, few weeds were present (<15 weeds 100 $m^{-2}$), with fat hen comprising >50%. At the time lettuces were harvested, biomass of weeds capable of setting seed was still extremely low (no more than 6 g $m^{-2}$ biomass).

As both short and long-term strategies received 1.00 kg ha$^{-1}$ of pendimethalin, differences in weed numbers between them reflect experimental variability. These strategies had the greatest weed biomass, including London rocket, green amaranth, fat hen and bittercress. Populations of these species were probably sufficient for some seedbank renewal. Increasing the pendimethalin rate to 1.32 kg ha$^{-1}$, combined with a late hand-weeding, virtually eliminated London rocket and green amaranth populations within the lettuce (Figure 2). Some fat hen and bittercress did escape, however these small plants had much-reduced potential to contribute to the seedbank. Where pendimethalin and propachlor were sprayed, nearly all weeds except fat hen were eliminated. Surviving fat hen were stunted; with similar seed production potential to the small weeds noted in the eradication treatment.

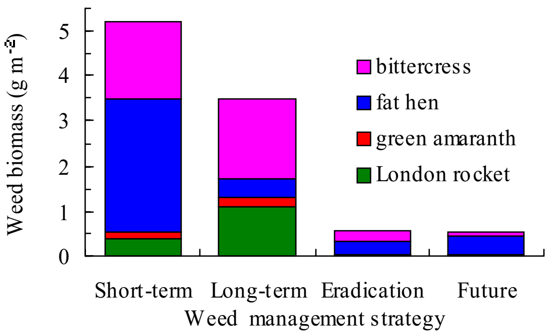


**Figure 2.** Weed management strategies affect final biomass of weed species in a lettuce experiment.

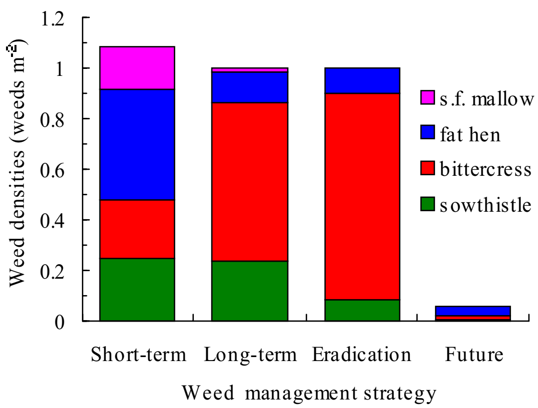


**Figure 3.** Weed management strategies affect relative abundance of four weed species 62 days after transplanting a cabbage experiment.

Costs of the four weed management strategies varied from \$A40 ha$^{-1}$ for the short and long-term treatments, \$A75 ha$^{-1}$ for the eradication treatment (including hand-weeding costs), and \$A100 ha$^{-1}$ for the future treatment. Although these differences are substantial, they are only minor components of overall production costs. More important are impacts on lettuce yields, and long-term economics. If, for example, reduced yields in the future treatment are real, this loss is worth \$A220 ha$^{-1}$.

Assuming a benefit from controlling weed seed set, I consider the optimal weed strategy in this experiment to have been the practices making up the eradication treatment. Costing \$A73 ha$^{-1}$, this strategy did not adversely affect lettuce yields, yet minimized seedbank additions. A single hand-weeding in the short-term or long-term strategies may have achieved a similar result. Increased costs and crop damage risks associated with the future strategy suggests propachlor would only be used where weeds poorly controlled by pendimethalin (e.g. yellow weed) are present.

**Cabbage** There was substantial germination of burr medic midway through the experimental period. This species thrived in all plots, less so in areas treated with oxyfluorfen. Not considered a significant competitor, it remained uncounted, and was not removed during hand-weeding. By harvest, the amount of surviving medic may have concerned commercial producers.

Because of minimal weed numbers, differences in cabbage growth or yields were probably due to weed management strategies or other agronomic influences. At 15 DAP, cabbages from oxyfluorfen treated areas were significantly taller (15%), but had slightly more necrotic leaf tissue than plants under other treatments. Contact of cabbage leaves with oxyfluorfen-treated soils may have damaged leaves soon after transplanting. However, by 39 DAP, there were no differences in death rates (average 2.6%) nor widths of cabbages (average 46.6 cm) across weed management strategies.

Weed management strategy had no effect on the number of marketable cabbage heads, averaging 18 700 ha$^{-1}$. Although there were slightly lower yields in areas sprayed with pendimethalin and propachlor (44.7 t ha$^{-1}$), compared to areas sprayed with metolachlor (47.2 t ha$^{-1}$), or oxyfluorfen (46.5 t ha$^{-1}$), these trends were not significant.

Weed species present included sowthistle (*Sonchus oleraceus*), bittercress (*Coronopus didymus*), fat hen (*Chenopodium album*), small-flowered mallow (*Malva parviflora*), and burr medic already mentioned.

When all treatments were hand-weeded 62 DAP, there was just over 1 weed m$^{-2}$ in all strategies except the *future* treatment, where abundance was reduced by 90%

**Table 1.** Costs ($A ha$^{-1}$) of four weed management strategies.

| | Short -term | Long -term | Eradication | Future |
|---|---|---|---|---|
| Herbicides | 79 | 107 | 142 | 71 |
| Application | 5 | 10 | 10 | 5 |
| Hand-weeding | 414 | 597 | 392 | 256 |
| Total | 498 | 714 | 544 | 332 |

(Figure 3). The various herbicide combinations resulted in very different weed species densities. Compared to metolachlor at commercial rates, or the long-term strategy, spraying 1.00 kg ha$^{-1}$ of pendimethalin and 4.32 kg ha$^{-1}$ of propachlor reduced sowthistle numbers. Combinations of pendimethalin and propachlor were less effective against bittercress than was metolachlor, while the former gave superior control of fat hen. Small-flowered mallow was killed by all herbicides except metolachlor. Pre-transplanting application of oxyfluorfen gave best control of all weed species.

Hand-weeding was required for all strategies, due to potential competition from several species. The combination of thick burr medic understorey and cabbage leaf canopy inhibited substantial germinations of late weeds in all plots. Thus, apart from the burr medic, there would probably have been few additions to the seedbanks of other species. The future strategy took least time to hand-weed. Plots where higher rates of pendimethalin and propachlor were used took less time to weed than lower rate counterparts, despite similar weed numbers.

The weed management costs of each strategy are detailed in Table 1. The main determinant of short-term cost is amount of hand-weeding required.

Although substantial in comparison with each other, these differences are less significant in the context of overall production costs; of equal importance are strategy impacts on cabbage yields, as well as long-term production economics. For example, if yield drops in long-term and eradication treatments (compared to the short-term strategy) were real, they could be worth about $A500 ha$^{-1}$. In this experiment I considered the optimal weed strategy the combination of practices making up the future treatment. With lowest cost, yet most effective weed control, this strategy did not adversely affect cabbage yields, yet minimized potential additions to the seedbank. Unfortunately, oxyfluorfen is not yet registered for use in brassica crops. Registration of oxyfluorfen for this use is an important adjunct to long-term weed management in vegetable enterprises, and should continue to be pursued. Not only is it a very cost-effective option, its different mode of action also reduces the risk of developing herbicide resistant weed populations.

Depending on weed species present, either the short-term or eradication herbicide treatments may have been the next best option (provided there was no yield suppression from the latter). For example, the sole use of metolachlor should be avoided in situations where fat hen is prevalent. Producers should look to herbicide rotation to reduce risks of developing resistant weed spectrums. Strategies need to take into account management of burr medic, which is poorly controlled by currently registered herbicides.

## ACKNOWLEDGMENTS

I gratefully thank the Queensland Fruit and Vegetable Growers and Horticultural Research and Development Corporation for their continued financial support of this work. The assistance of Mick Webber, and staff at Gatton Research Station, is sincerely appreciated.

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