Agronomic and economic evaluation of weed management methods in organic herb and vegetable production systems

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Abstract

Weed management is reported to be a major constraint in organic agriculture. Organic growers also report a lack of information about non-chemical weed control. A series of field trials was conducted in lettuce (*Lactuca sativa* L.) and echinacea (*Echinacea purpurea* (L.) Moench) crops to evaluate a range of weed control methods commonly used in organic herb and vegetable production systems. The criteria for evaluating the methods were weed growth, crop yield and cost effectiveness.

Hand weeding, tillage and organic mulches (hay and pelletised paper) were effective to very effective at suppressing weeds. In general, good weed suppression was correlated with good crop yields; however, crop yields were reduced by tillage and paper mulch. Deducting the cost of the weed control method from the gross crop value caused a greater re-ranking of the treatment performance in lettuce than in echinacea. This is partly due to the different growing season lengths and market prices of the two test crops. The most cost effective methods for managing weeds in lettuce were tillage and hand weeding. When weed competition is low, the unweeded control treatment was also cost effective. In echinacea, hand weeding and hay mulch were consistently the most cost effective methods for managing weeds.

Key Words

organic farming, hand weeding, tillage, hay, paper mulch

Introduction

Whilst weed management in organic herb and vegetable production systems is widely reported to be a major constraint, a range of options have been developed in Australia to manage weeds organically (1). These organic weed management options vary depending on factors such as soil and climate, crops grown, weed species, organic farming experience and the farmers' attitudes. Organic growers have less access to relevant extension and production services than conventional farmers and commonly report a desire for more research and extension to be carried out (2).

In Australia, some research has been conducted on specific non-chemical weeding methods in herb and vegetable systems, including mulches and tillage (3, 4). However, few studies have been published examining the comparative economics of weed control in horticultural cropping in Australia, apart from that by Tyler (5). Several overseas studies have reported findings based on comparative trials of different weeding methods with an economic evaluation of each method used (e.g. 6).

Several key weeding methods are frequently used by a majority of Australian organic herb and vegetable growers (1), these include hand weeding, tillage and organic mulches. A series of experiments were conducted on two crops with differing growth patterns, lettuce and echinacea, with the objective of assessing the relative effectiveness of various weed control treatments in terms of weed growth, crop growth and cost of each treatment. A novel paper mulch was also used in the trials as this method was reported in the literature to be effective for weed suppression (3, 7).

Methods

The field experiments were carried at three sites over three consecutive summers on properties situated on the Northern Tablelands of New South Wales (30?S, 152?E, elevation 1000-1100 m). In 1998-1999, trials were conducted at Yarrowitch. In 1999-2000, trials were undertaken on the University of New England's research farms, Kirby Research Station and Laureldale Research Station. In 2000-2001, only Kirby was used due to poor growth and site variability at Laureldale. Lettuce (*Lactuca sativa* L. cv. Imperial Triumph) and echinacea (*Echinacea purpurea* Moench [L.]) were used as the test crops. They were planted as seedlings and grown for 7 and 21 weeks respectively.

Five weed control treatments were chosen, i.e. control (unweeded), hand weeding, tillage, hay mulch and paper mulch, with four replicates for each treatment. The treatments were laid out in a completely randomised design and the plots were 10 m x 2 m for lettuce, and 7 m x 2 m for echinacea. Hand weeding was done at 4 weeks after planting (WAP) for lettuce and at 4, 8 and 12 WAP for echinacea using a wheel-mounted stirrup hoe and a chipping hoe. Tillage was done at the same time as hand weeding, and consisted of removing weeds using a rigid tine chisel plough and hand chipping in the planting row between the crop plants. Mulches were applied after the crop was planted and plots were hand weeded at 4 WAP. The hay mulch, mostly ryegrass (*Lolium* sp.) and oats (*Avena sativa* L.), was applied to a thickness of 150 mm (9,500 kg/ha) and the paper mulch, composed of pelletised and dried waste paper slurry, was applied to a thickness of 50 mm (42,000 kg/ha). Paper mulch was not used in the 1999-2000 trials due to lack of availability.

Weed biomass was measured at harvest by collecting all weeds at ground level in a $0.5m^2$ quadrat placed in the centre of each plot, drying the plant material at 80?C for 72 hours and weighing. Crop biomass samples were obtained by collecting eight lettuces and 10 echinacea plants located in the centre of each plot. The lettuces were harvested at ground level, while the echinacea was removed whole with a garden fork and washed. Crop material was dried at 80?C for 72 hours and weighed. Gross crop value ($/ha) was calculated by multiplying the crop biomass (kg/ha) by the prevailing wholesale price ($/kg). The cost of each weed control treatment was calculated based on the cost of materials, the labour required and machinery usage. All other production costs were considered to be equal between treatments and were not included in calculating treatment costs. The adjusted crop value was derived by subtracting the cost of each treatment at each site from the gross crop value. Statistical analyses were carried out using S-Plus 2000?. Generalized Linear Models (GLMs) were used to test for trial, treatment and trial by treatment interaction effects, with checks carried out to ensure that the assumptions of the models were satisfied (e.g. mean-variance relationship). Treatment means were separated using contrast analysis and standard errors were used to indicate the variability of the means.

Results

Weed biomass

The weed biomass at harvest in the lettuce and echinacea trials is shown in Figure 1. Weed biomass in the lettuce crops differed significantly between the trials and treatments with a significant interactions between trials and treatments ($P < 0.001$). The control treatment produced the highest weed biomass (1,450 kg/ha averaged across all trials), followed by tillage (498 kg/ha) and then hay mulch (268 kg/ha). Weed biomass in the hay mulch was mostly due to germinating grass seeds in the hay, rather than pre-existing weeds. Paper mulch and hand weeding produced similar weed biomasses (both about 59 kg/ha). If expressed as a percentage of the weed biomass for the control treatment, this represents an average reduction of weeds by 96% for hand weeding and paper mulch, 80% for hay mulch and 66% for tillage.

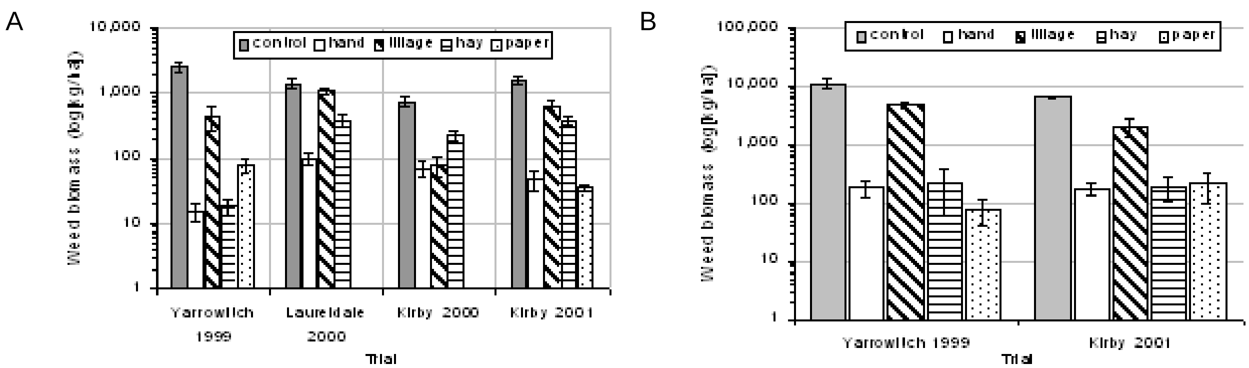
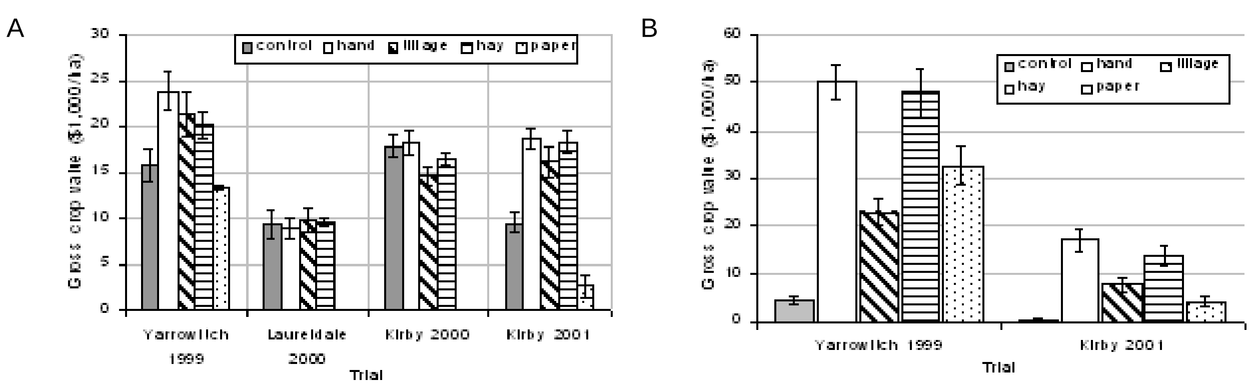


Figure 1: Weed biomass (log[kg/ha]) at harvest in (A) lettuce and (B) echinacea. The columns show the mean of each treatment at each site and the error bars show the standard error of the means.

The effects of trial and treatment on weed biomass in the echinacea crops were significant ($P = 0.006$ and $P < 0.001$ respectively), but the interaction was not significant ($P = 0.123$). The underlying weed load, indicated by the control treatment, was about 70% higher at Yarrowitch than at Kirby. Weed biomass was greatest in the control treatment (11,200 and 6,500 kg/ha at Yarrowitch and Kirby respectively) and moderately high in the tillage plots (average of 3500 kg/ha for both sites). The other treatments had relatively low weed biomasses, ranging from 150 to 200 kg/ha , and did not differ significantly ($P > 0.88$). A 60% reduction in weed biomass was observed for tillage, compared with unweeded plots, and the hand weeding, hay mulch and paper mulch treatments reduced weed biomass by an average of 98%.

Lettuce

Echinacea



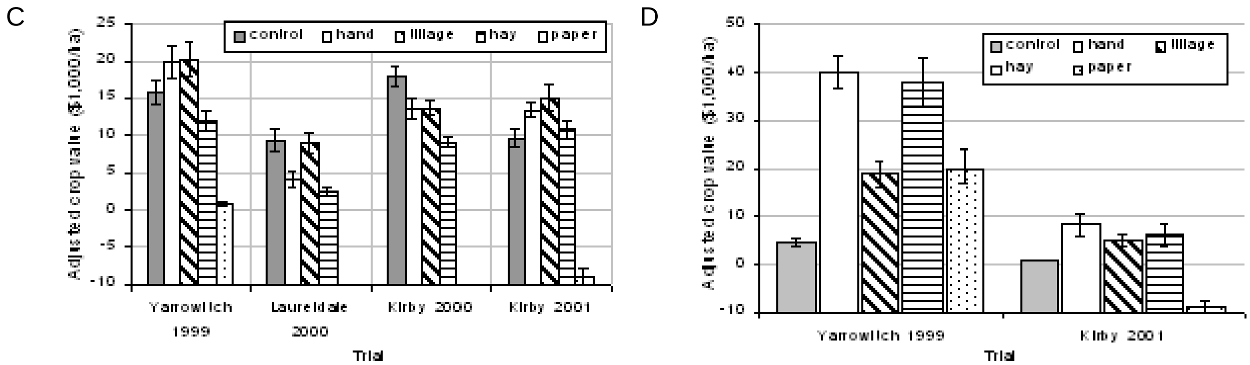


Figure 2: Gross crop value ($1,000/ha) and adjusted crop value ($1,000/ha) of lettuce (graphs A and C respectively) and echinacea (graphs B and D respectively). The columns show the mean of each treatment at each site and the error bars show the standard error of the means.

Gross Crop Value

The gross crop value (GCV) of lettuce in response to the treatments in each trial is shown in Figure 2A. The responses differed significantly between trials, treatments and the interaction was also significant ($P < 0.001$), however only the effects of the treatments are discussed in this paper. Averaged across trials, hand weeding and hay mulch produced the highest GCV (about $17,000/ha), whilst tillage was slightly less ($15,400/ha), though not significantly. Yields were reduced by 25% in the control treatment, and by 55% in the paper mulch.

Echinacea GCVs (Figure 2B) also differed significantly between trials, treatments and the interaction was significant ($P \leq 0.007$). Averaged across trials, the highest GCVs were observed in the hand weeding and hay mulch plots (about $32,000/ha). Tillage GCV was half that ($15,400/ha) and the control treatment produced yields about 90% less than the hand weeded plots ($2,700/ha). Yields for paper mulch were moderate at Yarrowitch, with a GCV about 66% of hand weeding and hay mulch and equivalent to tillage. However, at Kirby, paper mulch produced very poor yields with a GCV about 70% less than hand weeding and hay mulch, and about half that of tillage.

Cost effectiveness

The adjusted crop value (ACV) of lettuce is shown in Figure 2C. The effects of trials, treatments and their interactions were significantly different ($P < 0.001$). Averaged across all trials, the tillage, control and hand weeding treatments resulted in the highest ACVs ($14,600/ha, $13,300/ha and $11,700/ha respectively). Hay mulch, with an ACV of $8,700/ha, was significantly lower than tillage and the control, but not hand weeding. Paper mulch produced a very low ACV, giving a mean loss of $4,100/ha. The ACVs for echinacea (Figure2D) were also significantly different in response to trials and treatments and the interaction was significant ($P < 0.001$). Averaged across trials, hand weeding and hay mulch had the highest ACVs ($24,000/ha and $22,000/ha respectively), followed by tillage ($11,500/ha), paper mulch ($5,500/ha) and the control treatment ($2,700/ha).

Conclusions

- Weed control: hand weeding ≈ paper mulch < hay mulch < tillage < control. Hand weeding and mulching reduced weed biomass by 80 - 97%, tillage by about 60%.
- Crop value: hand weeding ≈ hay much ≈ tillage > control > paper mulch (lettuce), and hand weeding ≈ hay mulch > paper mulch ≈ tillage > control (echinacea). It is suspected that crop yields were reduced in tillage because of root damage and in paper mulch because of nitrogen immobilisation, and yields were lower in the control as a result of weed competition.

- Cost of treatments: paper mulch > hay mulch ≈ hand weeding > tillage > control.
- Lettuce: tillage and hand weeding were the most cost effective. When weed competition was low, the unweeded control treatment was also cost effective.
- Echinacea: hand weeding and hay mulch were consistently the most cost effective weeding methods.

Acknowledgements

Funding from the Rural Industries Research and Development Corporation and the University of New England is gratefully acknowledged.

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