The three forms of skeleton weed (*Chondrilla juncea* L.) in Australia differ in their susceptibility to herbicides

I.D. Black, R.N. Pederson and **D.W. Stephenson**[A], South Australian Research and Development Institute, Plant Research Centre, GPO Box 397, Adelaide, South Australia 5001, Australia.
[A] Present address: Mid Hills Animal and Plant Control Board, PO Box 54, Mount Barker, South Australia 5351, Australia.

Summary
Experiments on seedling and mature plants of three forms of skeleton weed (*Chondrilla juncea* L.) occurring in Australia demonstrated that there were differences in their short- and long-term susceptibility to the herbicides metsulfuron-methyl, clopyralid and 2,4-D amine. The narrow-leaved form was more susceptible to metsulfuron-methyl and 2,4-D than the other forms in the first three months after herbicide application. However it recovered more rapidly from the effects of 2,4-D than the intermediate and broad-leaved forms. Clopyralid and metsulfuron-methyl were less effective in killing the broad-leaved form than the intermediate and narrow-leaved forms. Clopyralid was the most effective herbicide on all forms. Clopyralid, metsulfuron-methyl and 2,4-D labels should be altered to take account of the form of skeleton weed targeted.

Introduction
Skeleton weed (*Chondrilla juncea* L.) occupies large areas of farm land in central and south-western New South Wales, northern Victoria and the South Australian Mallee. It is again a serious threat to farm production in south-eastern Australia, despite relatively successful biological control programs. This is because only the narrow-leaved form (A), which was predominant, has been effectively controlled by skeleton weed rust (*Puccinia chondrillina* Bubak & Sydow). As a result there has been an increase in the rust-resistant biotypes (intermediate (B) and broad-leaved (C) forms) in areas where skeleton weed appeared to have been successfully controlled. Additionally, there are continued new outbreaks of skeleton weed in Western Australia and Eyre Peninsula in South Australia.

In response to the resurgence of skeleton weed as a major problem, the Grains Research and Development Corporation and the Wheat Research Committee for Victoria sponsored a workshop on the management of skeleton weed in March 1991. Information presented at this workshop suggested that the broad-leaved form of skeleton weed appears to be less susceptible to some herbicides than the narrow-leaved form. In the South Australian Mallee, clopyralid gave only 50% control of the broad-leaved form at 300 g ha^{-1}. In contrast, the narrow-leaved form was usually well controlled by clopyralid at 150 g ha^{-1} (Heap and Fischle 1987, Heap 1991). Some evidence from the Victorian Mallee also suggested that the broad-leaved form was less susceptible to clopyralid than the narrow-leaved form (Pritchard 1991). However, this evidence was not conclusive because the different forms of the plant were not treated at the same experimental site. Consequently, one of the recommendations from the workshop was to confirm whether there were significant differences in the susceptibility of the three forms to herbicides commonly used for their control in cereals.

CSIRO Division of Entomology is continuing research in Europe to find rust strains for the control of the intermediate and broad-leaved forms of skeleton weed, and has recently released a promising strain for the intermediate form (Jupp 1997). However it is not yet known how effective this strain will be in the field. Therefore, herbicides may remain the primary means of controlling these forms.

The objective of the two experiments reported here was to determine whether there are significant differences in the response to herbicides of seedling and mature narrow-leaved (A), intermediate (B) and broad-leaved (C) forms of skeleton weed.

Materials and methods
Single experiments on seedling and mature plants were carried out at the Northfield Research Laboratories. Seeds of the three forms of skeleton weed were sourced from CSIRO Division of Entomology and Agriculture WA. They were germinated on moist filter paper in the laboratory in late March 1993 and five seedlings of each form were planted in separate bins in April 1993. Each 60 litre plastic bin buried in the field represented one treatment replicate. Bins were used in order to contain the root system of this Proclaimed Plant and they were disposed of at the end of the experiments. Plants not surviving the transplanting process were replaced as necessary. There were three replicates per treatment in a completely randomized design.

Herbicides were applied to plants in the seedling experiment on 24 June 1993 and in the mature plant experiment on 8 September 1994. For the seedling experiment, herbicides were applied through a calibrated knapsack sprayer in a specified quantity of water per bin, equivalent to 250 L ha^{-1}, to take account of the surface area of the bin but ensuring that little run-off from the skeleton weed leaves and stems occurred. The herbicides used were 0.9, 1.8 g ha^{-1} metsulfuron-methyl (as Ally®, 600 g kg^{-1}); 38, 75 g ha^{-1} clopyralid (as Lontrel®, 300 g L^{-1}) and 200, 400 g ha^{-1} 2,4-D amine (400 g L^{-1}). For the mature plant experiment, herbicides were applied through a calibrated bicycle sprayer with an output of 100 L ha^{-1} through Hardi Systems 4110-10 fan jets. In the mature plant experiment the aforementioned rates were used as well as 3.6 g ha^{-1} metsulfuron-methyl, 150 g ha^{-1} clopyralid and 800 g ha^{-1} 2,4-D amine. The rates were chosen to reflect labelled rates for control in cereals at the top end of the range and lower rates were used to help detect differences in susceptibility between the forms. Mixtures were not tested to avoid making the experiments too large and complex.

The assessments included EWRC ratings (Australian Weeds Committee 1978) where, on a log scale, 1 represents complete death, 9 represents no herbicide effect and scores of 1–4 represent commercially acceptable control. Per cent survival, visually estimated percent biomass (on a 0–10 linear scale converted to a percentage of the untreated score for the biotype), and fresh weight (g bin^{-1}) were also recorded.

Skeleton weed rust was not present on the A and B forms when the herbicides were applied in the experiments but appeared soon after. A fungicide was uniformly applied over the whole of the experiments to control the rust within two weeks of each occurrence.

The results were analysed using a factorial structure in a completely randomized design.

Two exploratory glasshouse experiments were carried out prior to the field experiments. They involved planting single seedlings in pots, spraying herbicide at the two lowest rates mentioned above for each herbicide and six replicates (pots) per treatment. Sprays were applied using methodology as described for the seedling experiments in bins and the assessments made were as described above. The results of these exploratory experiments are not reported here because they were only used to develop the assessment methodology for the bin experiments in the field.

Results

Mature plants

The experiment showed that there were differences in both the early and long-term response of the forms to the herbicides used.

Metsulfuron-methyl. The narrow-leaved form was most susceptible in the four months after application (Figure 1, T1–T3). There were small differences in biomass between the three forms (Figure 2) and metsulfuron-methyl killed fewer broad-leaved plants than those of the other forms (Figure 3).

Clopyralid. There was no significant difference between forms in their early susceptibility to clopyralid. Clopyralid suppressed plants more than the other herbicides (Figures 4, 5 and 6). Clopyralid killed fewer broad-leaved plants than those of the other forms (Figure 6).

2,4-D amine. The narrow-leaved form was affected more rapidly by 2,4-D amine than the other forms but it also recovered more rapidly (Figure 7). 2,4-D amine gave the lowest level of medium and long-term control (Figures 7, 8 and 9 compared with Figures 1–6). Initially, forms B and C were more tolerant to metsulfuron-methyl than to 2,4-D amine but metsulfuron-methyl was more effective than 2,4-D later (Figures 1, 2 and 3 compared with figures 7, 8 and 9).

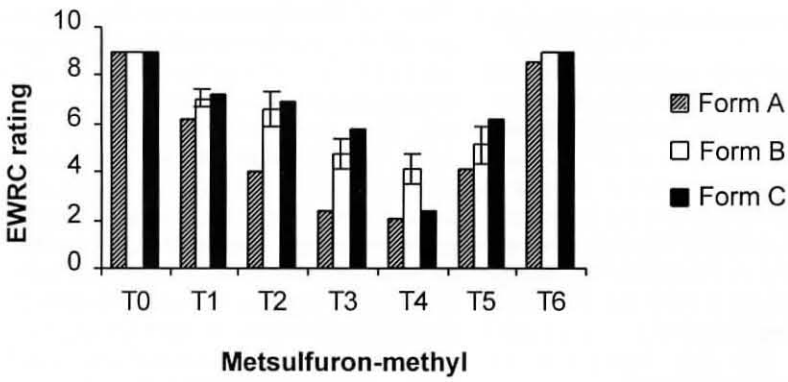


Figure 1. Effect of metsulfuron-methyl on mature plants.

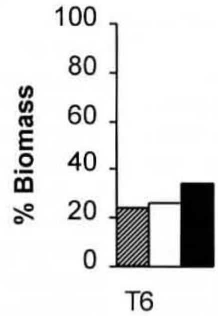


Figure 2. Effect of metsulfuron-methyl on biomass of mature plants after eight months.

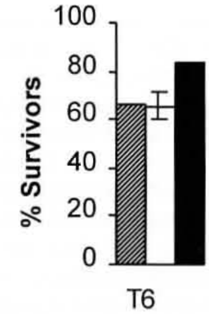


Figure 3. Effect of metsulfuron-methyl on mature plant per cent survivors after eight months.

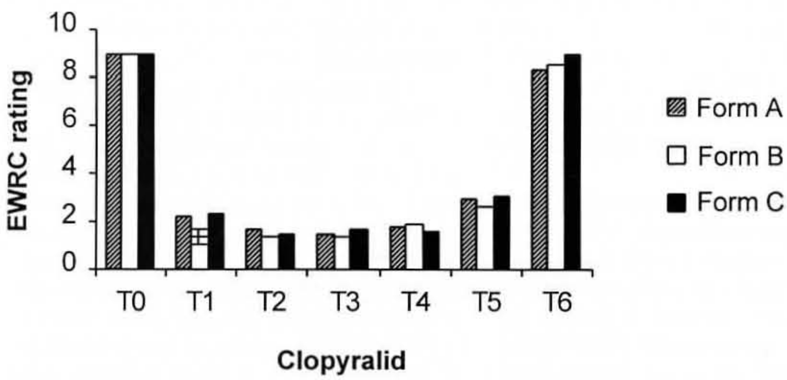


Figure 4. Effect of clopyralid on mature plants.

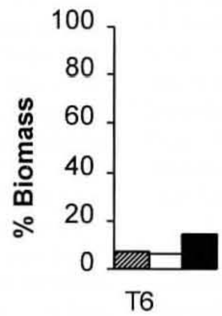
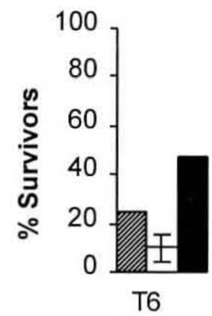


Figure 5. Effect of clopyralid on biomass of mature plants after eight months.



Figures 6. Effect of clopyralid on mature plant per cent survivors after eight months.

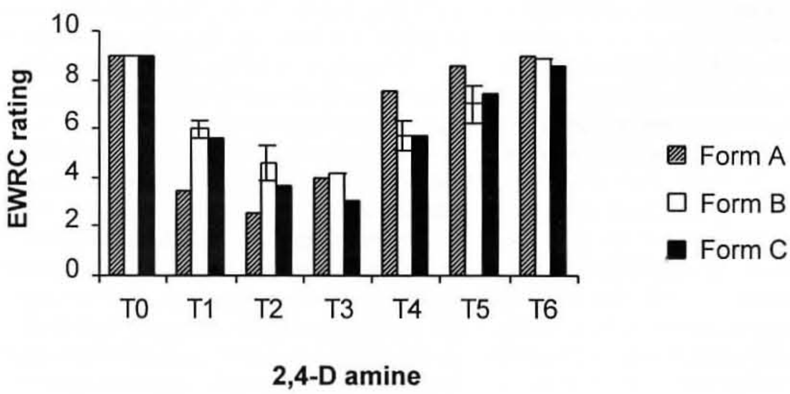


Figure 7. Effect of 2,4-D on mature plants.

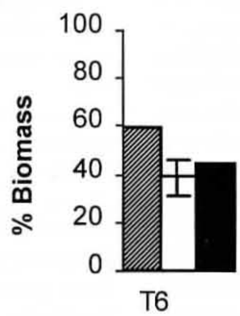


Figure 8. Effect of 2,4-D on biomass of mature plants after eight months.

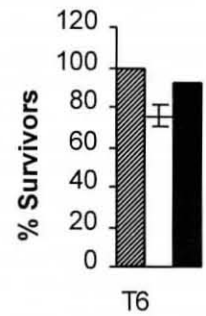


Figure 9. Effect of 2,4-D on mature plant per cent survivors after eight months.

Bars represent LSD ($P<0.05$). Where no bars are present there was no significant difference between treatments. T0=8/9/94, T1=4WAT, T2=7WAT, T3=10WAT, T4=17WAT, T5=26WAT, T6=34WAT, where WAT is weeks after treatment.

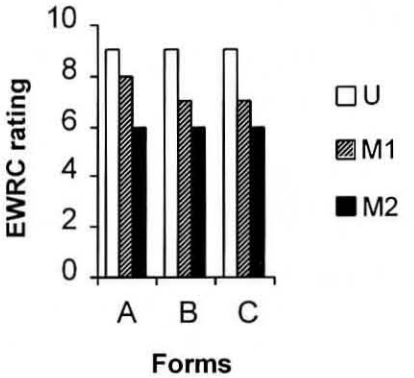


Figure 10. Effect of metsulfuron-methyl on seedlings as assessed four weeks after herbicide application.

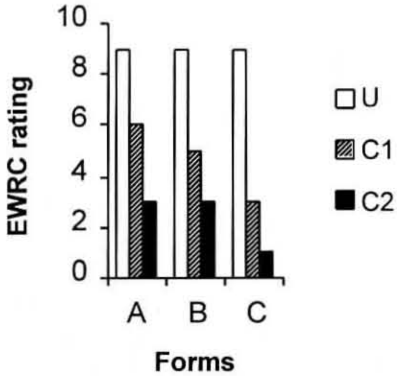
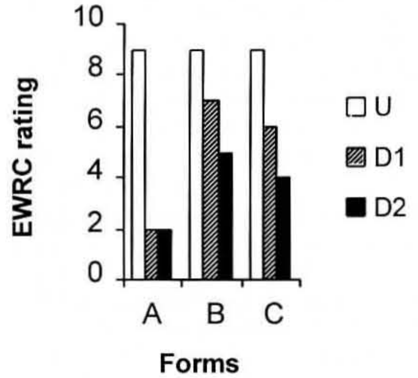


Figure 11. Effect of clopyralid on seedlings as assessed four weeks after herbicide application.



Figures 12. Effect of 2,4-D on seedlings as assessed four weeks after herbicide application.

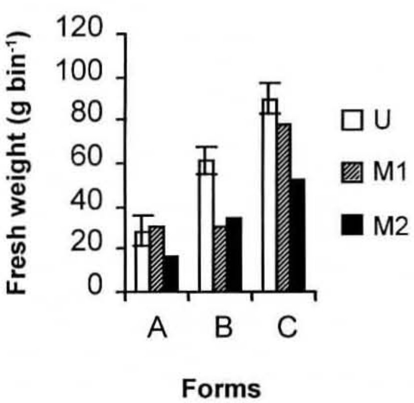


Figure 13. Effect of metsulfuron-methyl on the fresh weight of seedlings assessed seven weeks after herbicide application.

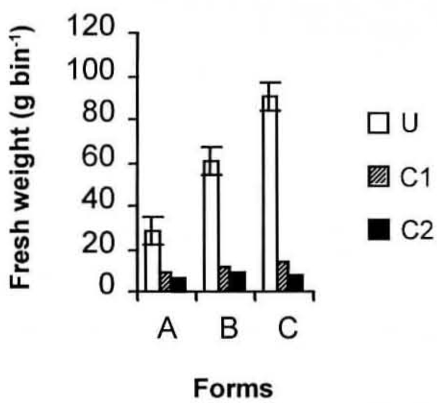


Figure 14. Effect of clopyralid on the fresh weight of seedlings assessed seven weeks after herbicide application.

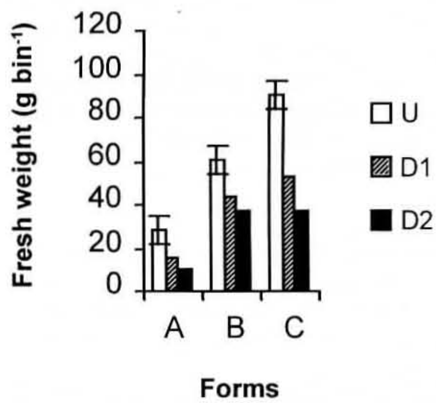


Figure 15. Effect of 2,4-D on the fresh weight of seedlings assessed seven weeks after herbicide application.

Bars represent LSD ($P<0.05$) in Figures 13, 14 and 15. In Figures 10, 11 and 12 the EWRC rating was estimated from detailed notes on the visible effects of herbicides on the treatments. Therefore no ANOVA was possible as there was only one value per treatment. U=untreated, M1=metsulfuron-methyl 0.9 g ha^{-1}, M2=1.8 g ha^{-1}, C1=clopyralid 38 g ha^{-1}, C2=75 g ha^{-1}, D1=2,4-D amine 200 g ha^{-1}, D2=400 g ha^{-1}.

By mid April, 1995 (34 weeks after treatment) all surviving plants had substantially recovered from the effects of the herbicides in terms of their appearance (Figures 1, 4 and 7; T6). However, clopyralid retarded plant growth more than metsulfuron-methyl which in turn had retarded growth more than 2,4-D amine (Figures 2, 5 and 8). Also, plant mortality differed between herbicides in the order clopyralid (highest), metsulfuron-methyl and 2,4-D amine (Figures 3, 6 and 9).

Seedlings

This experiment showed that there were differences between the forms in their susceptibility to low herbicide rates (Figures 10–15). The trends were similar to those expressed in the mature plant experiment. That is, the narrow-leaved form showed greater initial susceptibility to 2,4-D amine (Figure 12) and clopyralid was the most effective herbicide (Figure 14).

Discussion

An accurate assessment of herbicide effects in these and prior glasshouse experiments proved to be challenging. Because of large differences in early vegetative growth, in favour of the broad-leaved and intermediate forms, fresh and dry weight assessments in glasshouse experiments were obviously at variance with the level of damage observed in particular treatments. The prior glasshouse experiments were therefore valuable in choosing appropriate measurements for the bin experiments in the field. Similarly, at the last measurement date in the mature plant experiment, the plants had recovered in terms of healthy appearance but the surviving skeleton weed in the more effective treatments was much smaller than in the untreated controls. Therefore, a range of assessments was necessary to reasonably gauge the effect of the herbicide treatments.

It would have been useful to assess the interaction of the skeleton weed rust with the herbicides on the narrow leaved form. If further experiments are carried out, treatments with and without fungicide applications to the narrow leaved form should be included. We think that the rust would increase the difference in herbicide susceptibility between the narrow-leaved and the other forms.

We speculate that the more rapid recovery of the narrow-leaved form in the 2,4-D amine treatments may perhaps be due to reduced herbicide interception by the relatively smaller, narrower leaves, thereby reducing the amount to be detoxified by the plant. Less obvious explanations are needed to account for the relative resistance of the broad-leaved form to clopyralid and metsulfuron-methyl.

The results of these experiments confirm that there are differences in susceptibility of the different forms of skeleton weed found in Australia to the three herbicides commonly used for its control in cereal crops. This has practical implications. Farmers need to take into account the form of the weed they are targeting when choosing a herbicide program, with an increase in rate when dealing with the broad-leaved form. Labels of the herbicides used in these experiments should carry appropriate advice that differentiates between the forms. More generally, this work has implied that all herbicides and mixtures used for skeleton weed control may differ in their effectiveness on the different forms.

Acknowledgments
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