

Evaluating the Success of the Programme for the Biological Control of *Chondrilla juncea* L.

by
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INTRODUCTION

The term evaluation is in frequent usage recently. One is entitled to ask, what exactly do we mean by an evaluation programme? What should it consist of and to what extent is it justified?

What I want to try and do is to describe our approach to this problem in the case of skeleton weed *Chondrilla juncea* L., to present some of the results obtained and to see if there are any generally instructive points to be gleaned from this particular exercise. I feel this programme could be useful to look at at this stage, as it is not yet complete and the present situation has several aspects in common with partial or incomplete control results i.e. those whose evaluation is often more difficult but in many ways more useful.

What I am about to say can unfortunately be little more than a summary of a complex situation. Some aspects are already covered in published work (Cullen *et al.*, 1973, Cullen, 1974) others are still under study.

THE PROBLEM

A necessary starting point is to take a very close look at the problem or problems. These have been reviewed comprehensively elsewhere (Cuthbertson, 1967, Wells, 1971). The two major ones which have been examined are its competitive effect in wheat crops and its interference with harvesting machinery. *C. juncea* is a herbaceous perennial with a deep tap root which is very effective in removing nitrogen and moisture from the soil. The effect is important before a crop is sown and during the early stages of growth, as well as later on, and is therefore very difficult to combat with herbicides. Secondly at harvest, the tall tough stems of the weed become tangled with the machinery necessitating a large wastage of time and labour. This effect is generally reduced by a herbicide spray at an early stage of crop growth, which is however too late to affect the loss of yield from competition.

If as a result of biological control, the density of *C. juncea* were to decline to zero or even to the

level commonly observed in Europe i.e. 1/m², there would be no problem. However, apart from the level of unpredictability in programmes of importation, there were good reasons for considering it might not be possible to achieve this level in Australia. Wapshere (1971) has reviewed differences in agricultural practice and soil type which might increase the survival of *C. juncea* in Australia. While there are many areas of skeleton weed in Australia where the conditions described do not occur, it was certainly possible that an intermediate level of density might be the end result. The relationship between density and yield loss had therefore to be defined more exactly.

In fact, the data of previous workers (Cuthbertson, 1967, Wells, 1970) shows that there is a fairly simple logarithmic relationship. Table 1, based on data taken from the work of Wells (*loc cit*) summarizes this well and there is a natural division of density into the three categories presented. This table only shows the effect of competition for moisture. Similar figures for nitrogen are difficult to obtain so clearly, but a reasonable and acceptable conclusion is that at the high level of density (100 plants/m²) yield loss is usually 50% in a wet season due to competition for nitrogen only, and as high as 80% in a dry season due to competition for nitrogen and moisture.

Table 1

Average wheat yields in the presence of *C. juncea*. (excess nitrogen supplied but moisture limiting)

Density of <i>C. juncea</i> (rosettes/m ² in crop)	Yield (kgx100/ha)
1 - 10	13.85
11 - 100	7.54
>100	3.10

Data from Wells (1970)

THE METHODOLOGY

It was also relevant to ask how the hoped for decrease was to be achieved, and what effects of the introduced organisms were the most meaning-

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ful to measure. In fact a progressive weakening of the plant leading to death, during the pasture phase of a rotation was predicted, there being no evidence from Europe of significant attack during the crop phase. It was apparent that the process of attack and death must be monitored in pasture but the results could only be apparent in counts of density in wheat crops in winter, while the crop was at an early stage. This was the time to judge yield loss/density effects and to see the population of plants which would be producing stems at harvest.

RESULTS AND DISCUSSION

Table 2 shows the overall changes in density in continuous pasture at points representative of the major regions of *C. juncea* infestation in Australia. The rust *Puccinia chondrillina* has been common in all areas since autumn 1972 and the midge *Cystiphora schmidti* was established in approximately half the areas by the same time. It has since spread and is now found in all areas. These are the two major effective organisms.

Table 2

Mean density of *C. juncea* (rosettes/m²) in pasture in S. E. Australia. (winter counts, mean of 4 areas in each region)

	Canberra	Wagga	Mallee	Tamworth
1971	233	172	225	40
1972	140	241	256	23
1973	103	148	195	32
1974	65	162	168	14
1975	59	51	87	<1
1976		31		

A satisfactory downward trend is apparent though the major decreases have only taken place in the last two years.

Table 3

Density of *C. juncea* (rosettes/m²) within crop in 5 paddocks at Wagga, N.S.W. (winter counts, * = pasture)

	1	2	3	4	5	Continuous pasture
1971	*	*	*	119	*	172
1972	*	*	*	*	*	241
1973	72	91	34	*	37	148
1974	*	8	*	*	17	162
1975	24	14	*	*	*	51
1976	3	*	*	*	4	31

Table 3 shows the densities measured in individual crops grown alongside the continuous pas-

ture at Wagga. It shows the results during normal agricultural practice. Again, a substantial decrease is apparent.

The results are obviously encouraging, but one must continually ask two questions:—

1. Is this the end result or can we expect continued change?
2. What in fact have we gained so far?

Work is still in progress to answer the first of these questions. We require a rather careful analysis of the effects of rates of attack actually observed in the field both in terms of the actual damage done to the plant and what this means in the pasture and crop situation. I would like to refer to some of the work carried out so far. Table 4 shows the results of some work carried out by Groves and Williams (1975) and demonstrates the effect of a relatively infrequent rate of attack (every 14 days) by *P. chondrillina* on seedling growth of *C. juncea*.

Table 4

Increase in root dry weight of *C. juncea* uninfected and infected by *P. chondrillina*.

Days old	Uninfected	Infected	Infected / Uninfected X 100
63	0.21	0.11	52
90	0.51	0.17	33
106	0.68	0.29	43
120	1.31	0.35	27
146	2.87	0.85	30

mean = 37%

Data from Groves and Williams (1975)

Some preliminary work of ours on the recovery rate of root reserves in regenerating plants also indicates a severe depression of growth at a rate of an infection every six days. This infection rate has been shown to be considerably less than that usually experienced (Cullen *et. al.*, 1973). With more of this work, combined with careful field observation, it is hoped to analyse the process of population decline of *C. juncea*. At present all indications are that it will continue.

To answer the second question it is apparent that the changes in density have meant a downwards shift in the distribution of high, medium and low density areas. From the relationship between density and yield loss referred to earlier, it is apparent that there is some quantifiable benefit here.

However this is not all. We have observed a situation in Australia rather different from that in Europe. It is apparent that attack by *P. chondrillina*

and *C. schmidtii* is not confined to the pasture phase. Table 5 shows the extent of attack on *C. juncea* within the crop at a very early stage.

Table 5

Percent plants infected and mean level of attack (range 0-3) by *P. chondrillina* in pasture and in crop. (winter measurements, taken in 4 paddocks at Wagga, N.S.W.)

		1	2	3	4
		% level	% level	% level	% level
1973	pasture	63 1.7	58 1.6	58 1.8	60 1.7
	crop	50 1.6	54 1.7	37 1.5	93 1.9
1974	pasture	*	84 1.6	*	46 1.4
	crop	*	45 1.4	*	0 ¹ 0
1975	pasture	72 1.7	64 1.7	*	*
	crop	2 ¹ 2.0	59 2.0	*	*

¹ late planted crops.

The results are variable, depending on the amount of time between sowing and the examination, but most importantly, demonstrate that *P. chondrillina* is quite common at this stage. Once established in the crop, it persists, and thus *C. juncea* plants are not only fewer but weaker.

This result was not expected but is very significant at the present time. An idea of what is happening can be obtained from Table 6 which gives the estimated dry weight of the actual quantity of *C. juncea* plant material above ground, in winter

and the subsequent summer. (The figures for summer represent a period approximately one month after harvest but are very closely indicative of the level to be expected actually at harvest). With no disturbance or attack, there would normally be a vary significant increase, associated with the change from a flat rosette to an extensive aerial stem. This can be seen in the figures for 1971 for both pasture and crop situations, and the pattern can be seen to be repeated each year on the plot at Canberra, which is sprayed with a fungicide. By contrast, the figures for 1973 to 1975 for the crop situation at Wagga show not only initially low values but very small increases or even decreases by summer.

In effect this means that there is now only a weak spindly stem within the crop and no problem with harvesting, so the farmer no longer has to spray. On the basis of Table 6, the threshold above which there would be trouble with machinery would be between 10 and 15g/m².

The second point is that it is very clear that what is present in the crop right from the very beginning and in fact at all stages where *C. juncea* has been considered a major competitor, is a very much weakened plant.

The severe effects on root growth have been referred to previously and it is apparent that the strength of the plant's competitive effect has been

Table 6

Seasonal change in estimated dry matter equivalent (g/m²) of *C. juncea* growing in 5 paddocks at Wagga, N.S.W. and in a control area at Canberra.

		1	2	3	4	5	Canberra control. no <i>P. chondrillina</i> (pasture)
		(pasture)	(pasture)	(pasture)	(crop)	(pasture)	
1971	winter	29.81	52.64	14.44	15.72	10.32	21.82
(prior to <i>P. chondrillina</i>)	summer	34.15 ¹	135.60	53.03	82.61	39.86	49.47
1972	winter						12.04
	summer						49.50
				crop	only		
1973	winter	9.69	14.06	1.40	*	1.40	18.31
	summer	4.56	11.39	3.00	*	0.57	115.04
1974	winter	*	0.22	*	*	0.97	7.82
	summer	*	0.32	*	*	8.87	20.11
1975	winter	1.11	0.88	*	*	*	12.66
	summer	1.26	1.15	*	*	*	34.88

¹ *P. chondrillina* first established on this area and some effect noticeable in 1971.

reduced. In fact wheat classers and farmers have remarked on this effect in the field. It is unfortunately very difficult to quantify, however it is considered that a reduction in root growth to one third that of the control would mean at least a 25% reduction in the competitive effect.

ECONOMICS

There are thus three beneficial effects as far as wheat growing is concerned.

- (1) A steady reduction in weed density, expected to continue.
- (2) A reduction in vigour rendering the remaining weed less competitive.
- (3) A reduction in top growth resulting in no further hindrance to harvesting.

To turn to the economics of the situation, it is possible to quantify these effects in terms of the original problem, provided there is adequate information on the problem itself. It is necessary to take into account not only acreages involved, but the actual densities and distribution within crops, the availability and cost of alternative methods of control, the presence of other weeds and the variation between seasons and between regions.

Over this must be laid a similar variation in the actual control realized, and for predictive purposes, expected.

Finally, calculations can be made. It can be argued that much of the information as to the extent of the problem is difficult or impossible to obtain and it is true that some assumptions may have to be made. This emphasizes that all such calculations and assumptions should be subject to examination by independent agricultural scientists and economists. This exercise has been performed recently for the *Chondrilla* programme and the details will be published elsewhere. The results can be summarized in Table 7.

Table 7

Estimated annual and total savings to date due to biological control of *C. juncea*. (in \$million)

1972	0.06
1973	11.23
1974	13.64
1975	17.86

total to date 42.79

Estimated recurrent annual savings at final equilibrium
 = \$ 25.96 million
 (out of total possible annual loss of \$ 29.53 million)

This refers solely to the problems of competition and harvesting in wheat.

I do not feel that anybody concerned with the funding of biological control can deny that these figures are rather useful.

CONCLUSIONS

To return to the beginning, what should an evaluation programme consist of? Not unlike many other scientific studies, it is apparent that it should comprise a descriptive and an analytical phase. The descriptive phase has to be attuned very carefully to the nature of the problem and this in turn must be defined and quantified as well as possible. Fundamentally this phase must aim to accurately describe the current situation and its variation in time and space. This data provides the necessary framework for the analytical phase, which should be an attempt to explain why the system occupies a particular state. From this, it should be possible to predict the outcome and also hopefully, to suggest the most profitable means for improvement if such is necessary. It is also fair to say that despite commendable attempts by Wapshere (1975) and Harris (1973) we are a long way off being able to develop general principles in the field of plant population/insect population interactions, one main reason being a very real lack of data. Only better analyses can provide that data.

From the point of view of economics, it is apparent that an accurate description of the status of control is important, so too is a prediction of eventual outcome and the possibilities of improvement. If the biological data is available, economic quantification becomes possible. Without it, it is not. If it is worth investing in a biological control programme, it is worth that extra input to demonstrate whether the original investment is worthwhile.

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