AN ECONOMIC EVALUATION OF BIOLOGICAL CONTROL OF ROSE-GRAIN APHID IN NEW ZEALAND

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CONTENTS

ERRATA:

P.11 The ninth row of Table 5 should read as follows:
75000 32000 3668 1565 1223 522 611 261
i.e. replace the blank space with 1223 and 1223 with 522.

P.21 Paragraph 4 replace cereal aphids by RGA.

LIST OF TABLES

ACKNOWLEDGEMENTS

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SUMMARY

The rose-grain aphid (RGA) is an introduced pest which attacks cereals and can cause considerable loss of yield. It is a pest of some economic concern in affected grain growing areas of New Zealand. In 1985 the DSIR introduced a parasitoid, Aphidius rhopalosiphi, in an effort to control RGA by biological means. This study aims to perform an economic evaluation of the biocontrol of RGA in New Zealand.

RGA damage to cereal crops in this country was studied by the DSIR in 1983-84 and 1984-85, prior to introduction of the parasitoid. Using this work, estimates were derived of the annual cost of RGA damage to New Zealand's cereal crops. It was calculated that RGA could cause between $0.5 million and $10 million damage annually in Canterbury alone.

In addition to these costs, RGA acts as a vector for Barley Yellow Dwarf Virus disease which can cause losses of up to 20% - 30% in barley crops in localised areas.

Chemical control, the only suggested alternative to biocontrol of RGA, was estimated to cost at least $3.6 million annually, if it was to be effective.

The impact of the parasitoid on RGA has been rapid. In a short space of time it has become established throughout New Zealand and very high levels of parasitoid have been recorded. DSIR experts consider that the RGA has been controlled and will in future no longer be a pest of significant economic importance due to biocontrol.

An informal survey of a small number of Canterbury farmers offers confirming evidence that aphids are perceived as a problem on cereal crops and that aphid numbers appeared to have declined in the past two to three years.

The total cost of DSIR research into the integrated pest management of RGA is estimated to have been approximately $1.32 million (in 1988 dollars). The biological control component of this research cost about $264,000. Against this figure, estimates of the annual benefit of biocontrol range from $300,000 to $5 million, so that the DSIR's initial investment in the whole research programme is likely to be repaid in savings to the community within at most seven years under a 10% discount rate and conservative assumptions. If the biocontrol component of the research is treated separately, the costs of biocontrol have already been repaid.

The evaluation of biocontrol shows quite clearly that based on the data available, and assumptions made, this particular biocontrol project was fully justified on economic grounds. When giving consideration to such projects in future it will be important to perform at least a preliminary economic analysis before committing the required resources to them.

CHAPTER 1

Introduction and Farmer Survey

1.1 Introduction

The rose-grain aphid (Metopolophium dirhodum)(RGA) was first found in New Zealand in 1982. It is a pest which attacks cereals and can cause considerable loss of yield in cereal crops. RGA has also been implicated as a vector in the transmission of barley yellow dwarf virus disease. Chemical treatment with insecticides to control the aphid has been necessary in recent years. All these factors combine to suggest that RGA is therefore a pest of some economic concern in the affected grain growing areas of New Zealand.

In order to control the spread of RGA and limit the damage it might cause, in 1985 the DSIR introduced to New Zealand a parasitoid known to affect RGA populations in England and France. This biological agent, Aphidius rhopalosiphi, has since been released at a number of sites throughout Canterbury and also in Marlborough, Southland and Manawatu. The parasitoid has become well established in some districts (Stufkens and Farrell 1987a) and high levels of parasitism have been recorded (Farrell pers comm).

However, no attempt has been made to determine the economic benefits of biocontrol of the RGA. While the establishment of the parasitoid suggests that the biocontrol project has been successful, it is important to attempt to measure the success or otherwise of the project in economic terms. Economic benefits obtained from DSIR activities of this nature represent gains to the nation as a whole. From a social standpoint it is desirable to be able to identify these benefits in order to facilitate the efficient allocation of resources. It is also sensible to evaluate the project from an economic perspective to ensure that the considerable expense involved in undertaking the biocontrol of RGA was justified. In the foreseeable future, with constraints on finance for such projects becoming tighter, it will become increasingly important to perform such analyses prior to commencing research in order to identify those areas most likely to achieve significant returns.

The logical conceptual framework within which to carry out such an economic evaluation is cost-benefit analysis. A number of cost-benefit analyses of biological control projects have been undertaken in the past, although very few in New Zealand. Cost-benefit analysis essentially consists of enumerating the potential costs and benefits of a possible course of action, and where possible quantifying these costs and benefits. Available data gathered by the DSIR in the course of monitoring the RGA and the parasitoid enables reasonable estimates of the costs and benefits associated with this biocontrol project to be derived. Chapter 2 discusses the costs to New Zealand agriculture of RGA in the absence of any form of control. These costs may be identified as the cost of crop yield losses through direct RGA damage, the cost of yield losses through barley yellow dwarf virus damage transmitted by RGA, and the cost of chemical control of RGA.

In Chapter 3, evidence of the impact of the parasitoid on RGA is examined. Estimates of the economic benefit of the parasitoid are obtained. Chapter 4 brings together the estimates of the costs imposed by the RGA and the benefits of the parasitoid to derive an estimated net benefit or return from the biological control project. This represents an assessment of the economic gain to the nation as a whole from the biocontrol of RGA.

The following section briefly discusses the informal farmer survey conducted and some of the key findings of this survey.

1.2 Informal Farmer Survey

As the data regarding aphid damage leans heavily on DSIR research, it was felt to be desirable to obtain some input from affected farmers. In order to do this an informal telephone survey of Canterbury farmers was conducted. The names of several farmers who have had a past contact with Lincoln College were obtained from the Lincoln College Farm Management Department and ten farmers were telephoned and queried about aphids and crop management. Specifically, farmers were asked what crops they believed aphids to occur on in the greatest numbers, what crops, if any, had been sprayed specifically for aphids in recent years, and whether a decline in aphid numbers had been noticed over the last two to three years.

The results generally confirmed the DSIR research discussed in later chapters although the survey should not be construed as providing scientific evidence. Farmers differed over which crop, if any, appeared to attract most aphids with the usual perception being that most crops were at risk to similar degree. Barley was generally mentioned, but wheat was also felt to be prone to high numbers of aphids by some respondents. Only three of the ten farmers reported having sprayed for aphids in the past two years, and these were concerned about Barley Yellow Dwarf Virus disease rather than RGA control. These farmers sprayed insecticide or aphicide routinely on cereals, regardless of aphid numbers.

The general consensus was that aphid numbers had declined - some of the farmers volunteered their opinion that there were currently less aphids than in past years before being specifically asked. A number (3 of the 10) felt there had been no change while none of the farmers surveyed believed there had been an increase in aphids in the last 2-3 years.

Of the farmers surveyed, two were from the Southbridge area, three from the Leeston area, three from Irwell and two from Dunsandel. This represents a fairly localised region of Canterbury. There was a high degree of consensus between the respondents with most giving very similar answers to the questions posed. This admittedly very small and non-random sample of farmers gives at least some input to the analysis from sources outside the DSIR and the general unanimity of responses lends some weight to the results of DSIR research.

CHAPTER 2

Costs of Rose-Grain Aphid

2.1 Yield Losses for Cereal Crops

One major economic cost of RGA is the direct damage it may cause to cereal crops. This results in a loss of yield, which can have severe financial implications for farmers and the nation as a whole. This section reviews some of the literature on the effects of RGA on cereal crop yields, particularly under New Zealand conditions. Using this information, it aims to derive estimates of the economic costs of RGA to New Zealand agriculture in the absence of any form of control for the pest.

Unchecked, populations of RGA may reach very high levels. In 1984, a level of 240 aphids/tiller was recorded in spring oats grown at Lincoln (Stufkens and Farrell, 1985a). Such aphid levels have the potential to cause significant loss of yield in affected cereal crops. Yield loss caused by aphids may be due to both direct and indirect effects, according to Rabbinge et al. (1981). Direct consumption of the plants accounts for some of the yield loss but Rabbinge et al. also found that indirectly the honeydew secreted by aphids causes further losses by hindering photosynthesis and by promoting the growth of saprophytic fungi. Overall, a yield loss of up to 10% was found attributable to cereal aphids on winter wheat by Rabbinge et al. Prew et al. (1983) compared the effects of eight factors on the growth and nutrient uptake of winter wheat and found that the largest yield increases (up to 15%) were obtained by controlling for aphids and leaf diseases.

The DSIR has investigated the effects of RGA on cereal crop yields under New Zealand conditions. Stufkens and Farrell (1984 & 1985a) report the results of experiments in which cereal crops were treated with Pirimicarb to control for aphids. The yields of the treated crops were compared with yields from untreated plots. Aphid numbers on crops were also recorded in these experiments. Although there were variations between years, the results indicated that spraying for the RGA had a significant effect on crop yields. Table 1 summarises the results of these studies.

In discussing their results, Stufkens and Farrell (1985a) make a number of points regarding individual crops which are summarised below:

Oats. Oats may be regarded as being regularly at risk from RGA damage. Table 1 demonstrates that spraying for RGA on oats almost always gave a statistically significant improvement in yield, up to 41% in 1983-84 for spring oats.

Barley. Spring barley showed no statistically significant response to the insecticide in 1983-84 but in 1984-85 it was heavily infested and showed a significant response to spray treatment. It is possible that yield losses due to RGA damage were widespread in that season, according to Stufkens and Farrell. They state that "barley may be particularly subject to aphid damage varying in intensity from year to year under the influence of climate".

Wheat. Winter wheat supported relatively low numbers of RGA. It showed a significant yield response to Pirimicarb in 1983-84, but none in 1984-85. The 1983-84 results should be treated with caution, according to Stufkens and Farrell, due to the relatively low levels of infestation occurring on wheat (10-15 aphids per tiller in unsprayed plots) during the period of the trial.

The informal survey of Canterbury farmers enabled some further insights to be gained into the impact of RGA. It must be remembered that these results should not be construed as providing scientific evidence. In general farmers did not appear to be especially concerned about aphid damage. Although they were aware of the presence of aphids on their crops they had little idea what impact they might have on crop yields. Most identified barley or wheat as having aphid infestations in the past while oats were also mentioned by some. In general, there appeared to be little perception of different levels of infestation on different crops.

A difficulty with estimating the effects of RGA on crop yields is that aphid infestations may occur very heavily in a localised area, while other areas are unaffected. In New Zealand little or no data is available on the extent of RGA damage to North Island grain areas. These areas may have suffered only minor losses from RGA if aphid numbers are relatively low. However, some areas of the South Island appear to have suffered considerable damage as the Stufkens and Farrell studies show. The severity of aphid infestations also varies from year to year, depending on a complex combination of factors such as climate and interactions with predators.

In order to determine the economic impact of RGA in the absence of control measures it is necessary to make a number of assumptions regarding factors such as the level of damage likely to be caused by the pest, the average size of New Zealand's cereal crop harvest, and the value of the crops affected.

Using the Stufkens and Farrell data summarised in Table 1 as a guide, Table 2 shows estimates of high, medium and low levels of yield loss assumed to be inflicted by RGA on national wheat, barley and oats production. While these figures are estimates, they do fall within the range of yield losses reported by Stufkens and Farrell based on their research at Lincoln. It may be arguable whether or not the "high" levels of loss would occur nationally. However, the DSIR research certainly indicates that losses caused by RGA may have reached these levels in the Lincoln area in the past.

Table 1
Percentage Increases in Yield from Spraying for RGA

	1983-84				1984-85			1984-85
Crop	E10[1]	E50[1]	L10[2]	L50[2]	GS41[3]	GS55[3]	GS41+GS55[3]	Courtenay[4]
Spring barley	5	7	1	-	14	8	11*	16
Autumn barley	5	-	-	-				
Spring oats	28*	41**	16	9	13*	4	10*	
Autumn oats	12*	5	-	-				
Spring wheat	1	-	9	-				
Autumn wheat	10*	-	1	-	6	5	4	

Notes:

- indicates no insecticide applied
1. E10, E50 refer to early spray starting date at any stage when aphid density reaches a threshold of 10 or 50 aphids per tiller, respectively.
2. L10, L50 refer to late spray starting date at flowering stage when aphid density reaches a threshold of 10 or 50 aphids per tiller, respectively.
3. Spray applied at GS (growth stage) 41, 55 or both. Zadoks et al. (1974) describes the growth stage definitions used.
4. Unreplicated trial.

* $P < 0.05$ for comparison with untreated
** $P < 0.01$ for comparison with untreated

Source: Adapted from Stufkens and Farrell, 1984, 1985a.

Table 2
Assumed Yield Losses Due to RGA Damage (%)

Crop	High	Medium	Low
Wheat	10	5	0
Barley	15	7.5	1
Oats	30	10	5

The extent to which wheat is at risk is also problematical. Farrell (pers comm) feels that in New Zealand wheat is unlikely to suffer much damage from RGA, based on DSIR research. Surveys have shown consistently lower numbers of RGA on wheat than on barley or oats in Canterbury (Farrell and Stufkens 1988b). However, some of the Canterbury farmers spoken to had sprayed wheat to control aphids and did not perceive aphid numbers to be lower on wheat than other cereals. Overseas research also indicates that wheat may be susceptible to aphid attacks although much of this work was done in 1979 when heavy flights overcame wheat resistance to RGA (Farrell pers comm.). Because of these apparent contradictions, the "low" damage level for wheat was assumed to be 0% (as Farrell would suggest) while the "high" figure was set at 10%, about that found in overseas studies and recorded by Stufkens and Farrell on autumn wheat in 1983-84. It should be emphasised that these yield loss assumptions are intended to provide a basis from which to calculate the likely range of crop damage rather than to estimate accurately the extent of that damage.

Table 3 shows some details of recent trends in New Zealand grain production. The latest data available from the Department of Statistics at the time of writing is for the 1986-87 year. However, areas sown and total production of cereals for 1987-88 are thought to have been lower than for 1986-87, particularly for wheat which is estimated to have declined by about 35%. The effects of the drought in Canterbury and South Canterbury will also result in much lower yields in the 1988-89 season. Ministry of Agriculture and Fisheries forecasts of production in 1988 and 1989 are included in Table 3. Due to relatively low world prices for grain and the financial difficulties of the arable sector it is unlikely that New Zealand grain production will rise significantly in the near future although recent news is that cereal acreage will rise in 1989/90.

Approximately half to two-thirds of New Zealand's cereal crop is grown in the Aorangi and Canterbury local government regions so that any losses in these areas can significantly affect overall national production. For instance, a 15% yield loss in barley grown in Canterbury alone equates to approximately a 3% loss nationally even if no other area is affected. If Aorangi suffers a similar loss as well, this then represents 8% of the national barley crop. This suggests that the medium level of yield loss shown in Table 2 may potentially have occurred in the past, if the findings of DSIR research can be applied to the whole Canterbury/Aorangi region. The yield loss estimates therefore represent plausible bounds on the levels of damage caused by the RGA.

Table 3
Areas and Yields of Crops

	1983-84		1984-85		1985-86		1986-87		1987-88		1988-89	
									.... forecasts			
	Area Sown ha	Total Yield tonnes	Area Sown ha	Total Yield tonnes	Area Sown ha	Total Yield tonnes	Area Sown ha	Total Yield tonnes	Area Sown ha	Total Yield tonnes	Area Sown ha	Total Yield tonnes
Wheat												
N.I.	7856	38702	11245	48745	11817	48404	12602	49927				
S.I.	60824	275854	60598	260846	79718	331310	70361	286896				
Canterbury	45554	205475	49158	207142	64742	262281	56502	218834				
N.Z. Total	68680	314556	71843	309591	91535	379714	82963	336823	53000	228000	50000	210000
Barley												
N.I.	20852	95769	22974	95357	22737	87684	17176	68949				
S.I.	104563	475241	129358	549012	115814	468511	85307	331696				
Canterbury	71966	321083	91281	371329	83481	319372	62336	226325				
N.Z. Total	125415	571010	152332	644369	138551	556195	102483	400645	86000	378000	83000	350000
Oats												
N.I.	1752	6017	1145	3880	1267	4080	1777	6030				
S.I.	17994	68754	12315	47102	14611	55829	18970	72580				
Canterbury	9716	36064	5638	19897	7456	25031	10243	34069				
N.Z. Total	19746	74771	13460	50982	15878	59909	20747	78610	21000	78000	20000	75000

Note: Canterbury includes Canterbury and Aorangi Local Government Regions for 1984-85 onwards.
Sources: New Zealand Department of Statistics, MAF.

In the past, approximately 85% to 90% of New Zealand wheat has been milled, with the remaining 10% to 15% used for feed. Similarly, about 85% of barley is malted and 15% used for feed, on average. These ratios can be expected to continue to apply in the foreseeable future with minor variations from year to year. It is important to allow for these proportions in valuing the damage caused by RGA because of the lower prices attached to feed grain.

In general, grain prices vary from year to year due to factors such as world market conditions and local production and demand levels. For the purposes of estimating the cost of RGA damage the actual prices applying in any one year may not necessarily be appropriate. MAFCorp produces annual estimates of product price assumptions to be used for planning purposes which are likely to be a sounder basis for this analysis. Their projections for cereal crops, in 1 January 1988 dollars, are presented in Table 4. These prices are medium term average projections and are intended to be used specifically for planning purposes. As such these prices are also suitable for use in cost-benefit analysis.

Table 4
Agricultural Crop Values

Crop	Mean at Farm Gate $ per tonne	Standard Deviation
Wheat - milling - N.I.	223	32.7
- S.I.	210	32.7
Wheat - feed	163	26.6
Barley - feed	153	26.6
Barley - malting[1]	210	41.4
Oats	163	26.6

Notes: 1. A price differential of about $45 per tonne is expected between N.I. and S.I. malting barley
Dollars are as at 1 January 1988.

Source: MAFCorp Product Price Assumptions

Combining the estimates of yield loss with a range of projected grain production levels and the MAFCorp prices enables the calculation of a range of estimated losses for each crop due to RGA damage in the absence of control. Table 5 summarises some results from such calculations.

Table 5
Estimated Cost of RGA Damage ($1988)

Crop	NZ Total Production tonnes	Canterbury[1] Production tonnes	Level of RGA Damage / Infestation: High N Z	High Canty Only	Medium N Z	Medium Canty Only	Low N Z	Low Canty Only
			'000 dollars					
Wheat	330000	215000	6765	4408	3383	2204	0	0
	210000	135000	4305	2768	2153	1384	0	0
	200000	130000	4100	2665	2050	1333	0	0
Barley	500000	280000	15000	8400	7500	4200	1000	560
	400000	225000	12000	6750	6000	3375	800	450
	350000	195000	10500	5850	5250	2925	700	390
	300000	170000	9000	5100	4500	2550	600	340
Oats	80000	35000	3912	1712	1304	571	652	285
	75000	32000	3668	1565		1223	611	261
	50000	21000	2445	1027	815	342	408	171

Notes: 1 Canterbury includes Aorangi and Canterbury local government regions
The different production levels reflect the likely range of production for each crop.

What these figures show is that even at low levels of production and low levels of damage, the RGA is likely to cause at least $1 million worth of crop losses annually if no control measures are taken. At 1987 production levels, high yield loss on a national basis would cost approximately $20 million. If yield loss is restricted to Canterbury, the loss would be about $10 million. In fact, it is probable that losses from oat growers alone may exceed $0.5 million per annum, and that damage to barley crops caused by the RGA results in crop losses worth $3 million to $4 million. Even the most conservative estimates, then, suggest the RGA to be of considerable economic significance. The Stufkens and Farrell studies suggest that at least one season with losses at the "medium" level may already have occurred, potentially costing over $10 million nationally. The magnitude of such losses indicates that even if RGA damage was confined to serious outbreaks in only some regions at periodic intervals it would still impose high costs on the nation as a whole.

While it is not possible to assess the likely damage the pest has caused in the past, some estimates of the potential costs may be made. By taking the average yield loss from the Stufkens and Farrell studies for cereals grown in 83-84 and 84-85, and valuing the loss of cereal crops grown in the Canterbury and Aorangi local government regions at the prices applying in those years, some further estimates may be obtained. Converting these estimates to

1988 dollars shows that if the yield responses recorded at Lincoln had applied to the entire Canterbury/Aorangi harvest in those years, losses of approximately $8 million and $15 million may have occurred in 1983-84 and 1984-85 respectively. As farmers may have used chemical sprays in those years, and the damage may have been variable across the province, these figures are not intended to reflect actual losses - they merely demonstrate the magnitude of losses which could have occurred.

2.2 Barley Yellow Dwarf Virus Disease

Barley Yellow Dwarf Virus (BYDV) is a disease which may infect cereal crops. The severity and extent of the disease varies from year to year. As reported by Stufkens and Farrell (1986b), BYDV was rare in Canterbury during 1983 and 1984. However, widespread BYDV symptoms were seen in winter barley in the Lincoln area in 1985 at a low rate of plant infection. The disease was locally severe at Lincoln where infection increased to 30% in winter barley and 80% in spring barley by late November 1985. RGA is a vector of BYDV in Australia (Waterhouse et al 1985) and Stufkens and Farrell (1986b) show that RGA is likely to be an important vector of BYDV in New Zealand.

The disease can cause yield loss and damage to cereal crops. In localised areas, losses up to 20-30% from BYDV are possible in severe infestations. Stufkens and Farrell (1986b) report one case where BYDV was associated with over 40% reject grain passing an A6 (2.4 mm slot) screen. Although losses vary from year to year, RGA has been clearly implicated by DSIR research as a major vector spreading the disease in cereal crops. It is therefore important to account for any costs associated with BYDV when estimating the costs imposed by RGA.

But in attempting to assess the costs of BYDV attributable to the presence of RGA a number of difficulties arise. Firstly, the localised nature of outbreaks, and the fluctuation from year to year, makes it very difficult to ascertain with any accuracy the national costs. Moreover, while it appears that RGA is the major vector for spreading the virus, the possibility that other vectors may be acting cannot be excluded. The cereal aphid, Rhopalosiphum padi, is known to be a vector and other aphids have also been found to spread the disease (Stufkens and Farrell 1986b). As well as reducing yields, the disease may also result in grain being downgraded and thus receiving a lower price. This in fact may be the most probable outcome of BYDV infection for a particular crop. But there is little data on the extent and likelihood of such downgrading.

Overall, the difficulties discussed prevent the accurate calculation of any loss attributable to RGA associated with BYDV disease. Stufkens and Farrell (1986b) estimated that throughout the mid Canterbury area the rate of infection of BYDV was about 1% or less in 1985 - a year in which BYDV infection was much greater than usual. Perhaps the best that can be said is that the disease is likely to result in at most a 1% reduction in overall national production of barley; but in most years the cost is likely to be negligible. At 1987 production levels, 1% of the national barley crop would be worth approximately $800,000 so that losses due to BYDV are unlikely to exceed $1M in any year.

2.3 Chemical Control Costs

In the absence of biocontrol attempts, the only practical option to control RGA in New Zealand is to spray with insecticides. Pirimicarb was used in the DSIR research discussed in earlier sections - as an aphid specific insecticide it has advantages for control of RGA because it is less likely to harm beneficial insects which prey on aphids. The levels of insecticide necessary depend upon the level of infestation. Overseas experience has shown that farmers spray too late to effectively control aphids (Carter et al. 1980) as aphid build-ups can be difficult to detect. Farmers questioned in the Canterbury area appeared to have preferred not to spray for aphids unless a serious problem was apparent. Some, however, did include an insecticide or aphicide in sprays on cereal crops in order to control BYDV. It would seem therefore that the actual costs of chemicals used in aphid control in the past are relatively low. However, chemical control represents an alternative to biocontrol. Therefore, the costs of ongoing chemical treatment can be compared with the costs of developing a successful biological control regime.

One or two applications of Pirimicarb at a rate of 125 g/ha was recommended for effective control of RGA by the DSIR. It was found that two applications were needed at times. From price information available in the 1988 Financial Budget Manual published by Lincoln College, a single application of Pirimicarb at the recommended rate costs $11.30 per hectare, approximately, for the chemical alone. Application costs would depend on the method used, but for example, aerial application would cost about $27-$30 per hectare while contract spraying could cost between $13 and $18 per hectare. These figures are again taken from the Financial Budget Manual. Therefore, assuming only a single application was used with contract spraying at $13 per hectare, in order to chemically treat the entire New Zealand cereal grain crop - an area of at least 150,000 ha - the minimum cost would be $3.6 million at 1988 cost levels. Taking into account the possibility of a need for two treatments, and a likelihood of higher application costs in some cases, a figure of up to $5 million for chemical control costs does not appear unreasonable. This represents an annual outlay necessary to be reasonably confident of preventing RGA damage. Compared to the potential losses calculated in the previous section the cost of chemical treatment at $3.6-$5 million annually appears justified if this is the only alternative for effective control of the pest. Biological control, if effective, represents a much cheaper alternative. The effectiveness of biocontrol is discussed in Chapter 3. It should be stressed that the figure of $3.6 to $5 million is the estimated cost of effective chemical control, not the actual current costs of such control. The current practice of most farmers is not to spray crops unless significant aphid numbers are present.

2.4 Summary of the Costs of Rose-Grain Aphid

The preceding sections have examined some of the major economic costs RGA is likely to impose on the New Zealand arable sector. Estimates, or ranges, of these costs were determined. The following table summarises the costs of RGA calculated.

Table 6
Annual Costs of RGA ($1988)

Direct Costs - loss of yield	$1m-$20m average approx. $5m-$6m
Cost of BYDV	$0-$1m
Cost of Chemical Control	$3.6m-$5m

Some further costs of RGA may also be identified. These include damage to other plants and crops during overwintering of the aphid. Although Farrell and Stufkens found little evidence of this, overseas research indicates that roses and pasture may host RGA. Also, greenfeed oats were found to harbour significant numbers of the pest. In addition to direct yield loss associated with RGA damage, it is likely that crops will suffer stress which may lead to a lower quality of grain being produced. There is some evidence in published research to indicate that RGA may cause kernels to be smaller than on non-infested grain. No attempt is made to quantify these costs but they do represent real additional costs to be borne by the community.

Overall, it can be seen that in economic terms the RGA is a significant pest.

CHAPTER 3

Impact of Biological Control

3.1 Introduction and Establishment of the Parasitoid

Aphidius rhopalosiphi was introduced into New Zealand from Britain and France in April and June of 1985. The DSIR chose this species as a potential biocontrol agent for RGA because it was recorded as the most frequent parasitoid of RGA in southern England and in western France (Dean et al. 1981 and Rabasse and Dedryver 1983). Unpublished evidence from South American experiences also indicated that the parasitoid could effectively control RGA.

Stufkens and Farrell (1987a) describe how the parasitoids supplied from Britain and France were reared through three generations under laboratory conditions at the DSIR at Lincoln. Subsequently the parasitoid was released at a number of sites throughout New Zealand. Table 7 reproduces a table from Stufkens and Farrell (1987a) showing

Table 7
Numbers (x 1000) of A. rhopalosiphi mummies
at cereal sites between July 1985 and January 1987

Counties	No. of Sites	Releases 1985	1986	1987	TOTAL
Manawatu	1	5			5
Marlborough	3		3		3
Cheviot (C)	1			5	5
Eyre (C)	1		2		2
Ellesmere, Paparua (C)	6	149	6		155
Ashburton (C)	2	5	3		8
Southland, Wallace	6		3	5	8
TOTAL	20	159	17	10	186

Note: (C) = Canterbury counties

Source: Stufkens and Farrell (1987a)

details of the release programme which was undertaken. Altogether a total of 186,000 RGA mummies containing the parasitoid were released, mainly in Canterbury and other South Island cereal growing areas. These releases took place over a period from June 1985 to January 1987.

The spread and population of the parasitoid was monitored by surveying South Island cereal growing areas between November 1986 and January 1987. The results of these surveys are also reported in Stufkens and Farrell

Table 8
Recoveries of A. rhopalosiphi and hyperparasites from cereal sites (November-December 1986).

Values are for total sites surveyed, number of sites where A. rhopalosiphi was present, total A. rhopalosiphi recovered and numbers of the hyperparasites* reared from RGA mummies.

Counties	Total Sites	Sites Present	Total Recovered	No. Hyper- parasites
Marlborough	23	0		
Cheviot, Hurunui (C)	12	8	20	
Eyre, Oxford (C)	34	27	38	2
Ellesmere, Paparua (C)	54	32	75	6
Ashburton (C)	33	16	64	4
Strathallen (C)	10	7	30	
Southland, Wallace	31	3	18	1
TOTAL	197	93	245	13

Notes: * = Alloxysta infuscata, Pachyneuron aphidis, Dendrocerus sp.
(C) = Canterbury counties

Source: Stufkens and Farrell (1987a)

(1987a). RGA mummies were collected from nearly 200 sites and the emerging parasites identified. By late 1986 to early 1987 the parasitoid had become well established, as shown in Table 8 which is reproduced from the Stufkens and Farrell paper. No parasitoids were reported as recovered from Manawatu. However, 63% of surveyed sites in Canterbury yielded the parasitoid. Some recoveries from Timaru and Cheviot were 60-90 km from the original release sites approximately a year earlier, indicating a considerable dispersal.

On the basis of their surveys and other observations, Stufkens and Farrell (1987a) concluded that:

"The establishment of A. rhopalosiphi in Canterbury has been marked by rapid dispersal and distribution on a high proportion of cereal crops. Maximum population density of A. rhopalosiphi and parasitoid/prey ratios were comparable with those recorded in southern England and western France. The suitability of the Canterbury habitat for A. rhopalosiphi may be associated with the cycle of cereal crops and cereal regrowth in a mild maritime climate that allows survival and reproduction of prey and parasitoid throughout the year."

Since that time, unpublished recordings indicate the parasitoid to be widely established throughout the South Island. A. rhopalosiphi was found to be present at all sites sampled in Marborough, Canterbury and Southland (M. Stufkens, pers comm). The parasitoid has also established successfully in the Manawatu where levels of parasitism are similar to those in the South Island (P. McGregor, pers comm)

Given these findings there is reason to expect that the parasitoid has had an effect on RGA numbers since its introduction. The extent of this impact is explored in the following section.

3.2 Impact of Biocontrol

Since RGA first appeared in New Zealand in 1982, and the parasitoid was introduced in 1985, there was little opportunity to monitor RGA numbers in the absence of biocontrol. The limited published evidence suggests that RGA reached very high levels in some years, with peak concentrations ranging from 10-240 aphids/tiller in 1983 and 1984 (reported by Stufkens and Farrell 1984, 1985a, 1985b). Infestations of 50-150 aphids/tiller were recorded by Stufkens (unpublished) as early as December 1982.

In 1983 and 1984, Stufkens and Farrell surveyed cereal and grass paddocks for occurrence of RGA. Roses and sweet briar were also examined. In all, 20-100 sites on 1-4 days per month were surveyed. RGA was found to infest wheat, oat and barley crops in both seasons in the Lincoln area. Its annual cycle appeared to be largely restricted to cereal crops. The likely damage caused, and the cost of this damage, has been discussed in the previous Chapter.

Anecdotal evidence from Canterbury farmers also suggests that RGA was perceived as a potential problem on cereal crops during this period. Several of those spoken to commented that aphids had been especially bad three to four years ago. Following the release of the parasitoid, however, RGA has not occurred in the same concentrations and the informal survey conducted found no Canterbury farmers who have sprayed specifically for aphids since about 1984. Some continued to spray to control BYDV, however, or routinely treated crops regardless of aphid numbers.

The rapid establishment and dispersal of the parasitoid were discussed in the previous section. In addition to establishment, to estimate the impact of biocontrol it is necessary to examine where possible the influence A. rhopalosiphi has had on RGA numbers. In Stufkens and Farrell (1987a) the ratio of RGA/parasite numbers was examined for a number of crops at Lincoln in 1986. Maximum parasitoid to prey ratios were comparable to those recorded overseas. In November 1988, the proportion of parasitised sub-adult RGA was 60-90% in winter barley at Lincoln, 95-100% in spring barley at Lincoln and Rangiora, 65% on oats in Southland (Farrell pers comm) and 80% to 90% on spring barley in the Manawatu (P. McGregor pers comm). This research also indicates that RGA numbers are much lower than previously recorded levels. In fact, in sampling carried out at the end of 1988, the parasitoid was found to be more numerous than RGA at some sites. Whereas RGA numbers in earlier years rose rapidly to a peak in November, in the past two years this has not occurred. Farrell and Stufkens (1988a) showed that RGA maxima on spring barley and spring suction trap catches of RGA, declined greatly between 1984 and 1987. Farrell attributes this to the effect of the parasitoid which responds very rapidly to any increase in RGA numbers. Crop damage due to RGA has apparently been negligible.

In addition to its effect on RGA, A. rhopalosiphi has demonstrated the ability to parasitise other aphids, most notably the cereal aphid (CA)(Rhopalosiphum padi). While CA has not posed the same problems as the more recently introduced RGA, it is a known vector of BYDV and this unexpected side-effect represents an additional bonus from biocontrol.

Some hyper-parasitism of A.rhopalosiphi has been recorded, but as Table 8 showed, not to a great extent. Hyper-parasitism is not expected to significantly reduce the effectiveness of the parasitoid.

3.3 Probable Future Impact

The evidence so far collected by DSIR researchers, some of which has yet to be published, indicates that A. rhopalosiphi has become well established and has already reduced peak RGA populations. Based on these observations and overseas experience in countries such as Brazil and Chile which introduced the same parasitoid to control RGA in the 1970s, RGA is no longer anticipated to cause problems for cereal crops in New Zealand under normal seasonal conditions. Other countries which have introduced A. rhopalosiphi, or where the parasitoid occurs naturally, have few significant problems with cereal aphids. There appears no reason not to expect that biocontrol of RGA will therefore be maintained into the foreseeable future.

This statement must be qualified to a certain extent, however. It is likely that the use of insecticides on cereal crops may actually increase the damage caused by RGA. Stufkens and Farrell (1985) report the case of a barley crop at Templeton treated with Pirimicarb for RGA where after initially killing most of the aphids, a very rapid build-up in aphids occurred at the grain filling stage. This is attributable to the lack of predators, which were also affected by the insecticide.

Therefore, if chemical treatments are used in conjunction with biocontrol of RGA, a delicate balance must be maintained. Farrell (pers. comm.) suggests that no chemical treatments are necessary - better control may be achieved by allowing parasitoids and other natural predators to control the RGA. The experience of Canterbury farmers in the limited time since introduction of the parasitoid seems to confirm this view. Farmers spoken to were reluctant to apply insecticides because of their likely effects on predators.

Although the parasitoid has adapted successfully to New Zealand conditions, the relationship between the parasitoid and the RGA is dynamic. While all the indications are that the parasitoid will continue to exercise a high degree of control over RGA, the future level of control achieved is likely to fluctuate from time to time.

CHAPTER 4

Costs and Benefits of Biocontrol

4.1 Costs of Implementing Biocontrol

Selecting, introducing and monitoring a biocontrol agent is a lengthy and costly exercise. The DSIR investigation of RGA began in 1983 soon after the appearance of the pest. Their research continued until the end of 1988 - no further work is planned specifically to look at RGA as it is now felt that the pest is under control. Over the six year period in question quite significant resources have been committed to studying RGA and later the parasitoid, with two researchers working full time on the project. Clearly this represents a large investment by the DSIR.

According to the DSIR, the salaries of the researchers involved amounted to approximately $88,000 per year, in 1988 dollars. In order to calculate the full costs of research, salary costs have been multiplied by three to account for additional costs such as travelling and overheads. Therefore, the integrated pest management study of RGA cost $264,000 per annum. The DSIR estimates that over the six year period in question, five years of the researchers' time was devoted to specifically RGA research so that the total cost of the project is $1.32 million. Of this time, approximately one year was devoted specifically to biological control. The cost of the biological control component of the research is therefore $264,000.

The costs of introducing and releasing the parasitoid, and the costs of monitoring and studying the relationship between parasitoid and aphid, have been borne solely by the DSIR.

No further major costs are expected in future as the DSIR has concluded this phase of its research on cereal aphids and the parasitoid appears to be well established throughout the country. The estimate of $1.32 million therefore represents the full cost of implementing biocontrol.

Effectively this investment is a sunk cost. However, it can be compared with the expected benefits or returns from the biocontrol project to see whether the investment was justified on economic grounds, or to calculate a return on the expense incurred.

4.2 Benefits of Biocontrol

Chapter 2 discussed and where possible quantified the costs imposed by RGA on New Zealand agriculture in the absence of biocontrol. If biocontrol was to be 100% effective (RGA is eradicated) the benefits of biocontrol would be simply the sum of these costs, on an annual basis (In fact, eradication of RGA is not a possibility).

It is not fully clear which costs are appropriate, however. The greatest potential costs imposed by RGA related to the damage it caused to cereal plants and the consequent loss of yield. The extent of this damage was seen to be variable with the severity of infestation, which in turn depended on seasonal climatic conditions and other similar factors. Nevertheless, under moderate levels of infestation the cost of RGA damage in the absence of biocontrol (and hence the benefits of 100% biocontrol) were seen to be significant, of the order of \$3 million to \$7 million annually. However, if chemical control was used as an alternative to biological control, the annual costs would be from \$3.6 million to \$5 million. If it is assumed, as appears reasonable, that farmers would use chemicals to control aphids in a year of high infestation then aphid damage should be avoided even without biocontrol. In this case, biocontrol would save no more than the cost of chemical treatment - a maximum of about \$5 million annually (in 1988 dollars). Provided that chemicals are used effectively there should not be even the potential for crop losses (biocontrol benefits) of the 'high' orders of magnitude discussed earlier.

A number of questions could still be raised. Will farmers always use spray correctly to achieve full control? Some published evidence (Carter et al 1980) suggests not. Are outbreaks of aphids always detected? What impact will the use of chemicals have on the parasitoid? As has been noted earlier, Farrell reports some evidence suggesting that incorrect use of chemicals may actually benefit RGA by reducing predators. A degree of uncertainty surrounds the answers to many of these questions - the determination of precise benefits from biocontrol is not possible. The dynamic relationship between RGA and the parasitoid compounds this problem as the impact of biocontrol is likely to vary from year to year.

However, it is possible to determine what the range of the benefits will be, subject to a number of assumptions. Table 9 presents the benefits from increased yields given 10%, 50% and 90% effective biocontrol respectively under a range of levels of aphid infestation. This uses cost data from the calculations presented earlier in Table 5 of Chapter 2, with projected 1989 areas sown used as a basis, and summing losses/benefits over the three cereals wheat, oats and barley.

Table 9
Annual Benefits from Biocontrol
- Prevention of Yield Loss
($ 1988 '000)

Level of Damage/ Infestation	% of Control Achieved 10%		50%		90%	
	N Z	Canty Only	N Z	Canty Only	N Z	Canty Only
High	1850	1020	9240	5090	16630	9165
Medium	860	480	4310	2420	7760	4350
Low	130	65	660	330	1180	590

Notes : % Control Achieved refers to the % of RGA damage prevented by the parasitoid.
As before, Canterbury refers to the Canterbury and Aorangi local government regions

In the opinion of DSIR experts the level of control achieved by the parasitoid greatly exceeds 50%. Indeed, as suggested in Chapter 3, they believe the control to be such that RGA no longer poses a serious economic problem for cereal growers. At 90% control, the benefits of biocontrol range from $590,000 to over $9 million on an annual basis for Canterbury farmers alone. Even with a 50% reduction in RGA damage, given the assumptions described previously, biocontrol would save Canterbury/Aorangi farmers at least $300,000 annually. The overall national benefit could be significantly greater than this. Moreover, assuming that RGA infestations at much higher levels might occur periodically in the absence of biocontrol, the average annual benefits are also likely to be much greater. For the reasons discussed, a single annual net benefit figure is impossible to estimate, but the ranges shown are based on conservative assumptions.

A number of additional benefits are obtained from successful biocontrol. No attempt has been made in this study to value the benefit from the parasitoid attacking other aphids, notably the cereal aphid (R. padi) as well as RGA. The benefits calculated have included no allowance for crops other than wheat, barley and oats sustaining RGA damage. Green feed cereal crops would also appear to be at some risk from RGA. A further, non-measurable benefit is that biocontrol results in less use of chemicals which can be seen as beneficial for environmental reasons. Finally, no account has been taken of crop quality factors - however, it appears likely that RGA would reduce the quality as well as yield of cereal crops.

It is also likely that given the magnitude of savings involved some impact on areas of crops sown has occurred or will occur in future. This sort of interaction between yields and areas, and the effect this has on grain prices, is beyond the scope of the current study.

4.3 Summary of Costs and Benefits

The preceding sections have discussed the costs and benefits of biocontrol. Treating the overall DSIR research costs of approximately $1 million as an investment, the likely minimum expected annual benefit of $300,000 would 'repay' the initial $1 million outlay in just over six years, at a 10% discount rate. A discount rate of 10%, reflecting a time preference for money, is common in project analysis. After five years at a 10% discount rate, an annual stream of $300,000 would have an accumulated net present value of $1.31 million after six years and $1.46 after seven years. Even under conservative assumptions, then, the DSIR investment in development of integrated management strategies for RGA is likely to be repaid within six to seven years and to give positive returns in the longer term. The biocontrol component of the research, costing $264,000, would be repaid within one year.

The maximum annual benefit appears to be in the region of $5 million, assuming severe crop losses could be prevented by use of chemical sprays in the absence of biocontrol. This would represent a substantial immediate gain from the initial "investment" in biocontrol. Table 10 summarises the costs and benefits discussed so far and where possible quantifies these with values presented in earlier sections.

Table 10
Summary of Costs and Benefits of Integrated Pest Management, Including Biocontrol
(all figures in $ 1988)

Costs:	DSIR research $1.32 million approximately "sunk" cost /investment.
Benefits:	- Increased cereal crop yields: $300,000 to $5 million p.a. Original research costs repaid in 1-7 years at 10% discount rate. - Reduction in chemical costs: $3.6 to $5 million p.a. - Reduction of BYDV. - Spin-off attack of CA and other ahids. - Benefits to other plants e.g. greenfeed oats, roses. - Improved environment from reduction in chemical usage. - Improved grain quality.

CHAPTER 5

Conclusions

The preceding economic evaluation of biocontrol of the RGA has clearly shown that, based on the data available, and a number of reasonable (and fairly conservative) assumptions, the DSIR's biocontrol project was justified on economic grounds. Although there may be variations in the level of control from year to year, the analysis presented in Chapter 4 suggests that in future the annual return to the nation on the DSIR investment in research into integrated pest management of RGA is positive. It was found that the investment would be repaid within seven years even under very conservative assumptions. If the biocontrol component of the research was treated separately, the costs of this research would be repaid within a single year. In fact it appears possible that in the three years since introduction of the parasitoid it has already accrued benefits in excess of the costs of the DSIR's RGA research.

In the introduction it was stated that the benefits of biocontrol represent gains to the nation as a whole. However, it is obvious that some individuals benefit to a far greater extent than others - in this case those farmers in grain growing areas where RGA has been prevalent. The question of whether those who benefit should contribute in some way to the costs of research of this nature is beyond the scope of this study. This becomes a political rather than a strictly economic issue. It is a question that the DSIR may need to consider in the future, however, as it seeks funds to conduct long term research of this nature.

Few biocontrol agents are likely to prove as successful as A. rhopalisiphi appears to be. A fortuitous combination of climate and crop cycles appears to have aided the rapid establishment of the parasitoid and contributed to its success. While the biocontrol research has proved to be justified on economic grounds, when consideration is given to undertaking future biocontrol projects it will become increasingly important to perform at least a preliminary economic analysis before committing resources to them.

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