

EVALUATION OF CONSERVATION BIOLOGICAL CONTROL INNOVATION IN WINEGROWING

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Abstract

Conservation biological control (CBC) aims to improve conditions for natural enemies in agricultural landscapes and has the goal of reducing pest species below threshold level to thus avoid the need for synthetic chemicals. The CBC approach has been introduced in several counties, including New Zealand. Agricultural R&D is widely studied, however agricultural innovations and their adoption is less studied. A CBC practice introduced in Waipara vineyards is described in this paper and an evaluation of the uptake and economic sustainability of this innovation is provided. Results indicate that there are ongoing costs involved with maintaining the innovation and that adoption of the innovation is highly variable across winegrowing properties.

Introduction

The Greening Waipara Project began in 2005 and around 32 of the Valley's vineyards and wineries are now participating. The Project stemmed from initiatives by Lincoln University's Bio-Protection Research Centre, the Waipara Valley Winegrowers Association, the Hurunui District Council, and Landcare Research to make use of "nature's free services". The Project developed seven ecological innovations that could be implemented by wine companies in the Waipara Valley, including one focused on the control of leafrollers (*Planotorrix* and *Ctenopseustis* genera) in vineyards.

The wine industry in New Zealand has identified leafrollers as an important insect pest. Leafrollers on grapevines cause leaf, flower and fruit damage, and open berries to infection by the fungus *Botrytis cinerea* (Berndt, Wratten, Scarratt, 2006). Crop losses attributed to leafroller damage in the New Zealand wine industry have been estimated to cost up to NZ\$360/ha in a dry year and significantly more in wetter seasons (Lo and Murrell, 2000). The usual practice to control leafrollers in vineyards is the application of a broad-spectrum insecticide. One of the innovations introduced by the Greening Waipara Project involved the adoption of a CBC approach to reduce the incidence of leafroller amongst vines. The innovation used inter-row plantings of flowering plants (e.g. buckwheat) to attract parasitoid wasps, a natural enemy of leafrollers, into the vineyards. Research at trial sites revealed that adding flowering plants, such as buckwheat, into a vineyard ecosystem increased the impact of parasitoids on leafrollers (Berndt et al., 2006).

This study sought to understand how many of the vineyards had implemented the CBC innovation and the implications of this innovation in terms of costs and benefits. Dyllick and Hockerts (2002) stated that the concept of corporate sustainability integrates economic, ecological and social factors. However, it is apparent that many scientific projects encourage farmers to adopt ecological innovations without due consideration of economic factors. For instance, the Greening Waipara Project measured the success of the CBC innovation in terms of factors such as the number and fitness of the predators, the predation rate, the decrease in pest density and whether the pest population was brought below the threshold for insecticide application. There are very few examples in the literature of studies which have examined a CBC innovation from a business perspective. This study provides analysis of the success of the CBC innovation in terms of the adoption rate, as well as costs and benefits to the farmers.

Biological Control Literature

Biological control has been defined as "the intentional use by humans of parasitoid, predator, pathogen, antagonist, or competitor populations to suppress a pest population, thereby making the pest less abundant and damaging than it would be in the absence of these organisms" (Hoddle, 2004). It has been estimated that pests reduce global crop yields by 42 percent annually; pest management using biological methods are believed to provide 60 percent of the non-chemical control of these pests (Pimentel et al., 1997).

Biological control can take a classical or conservational approach, with classical biological

control being more widely represented in literature. Classical biological control involves the importation and release of exotic natural enemies to control weed or insect pests (Gurr & Wratten, 1999). This form of biological control has achieved numerous successes, but has also resulted in some well documented failures too, such as the introduction of cane toads in Australia. In contrast, conservation biological control (CBC) seeks to make better use of existing beneficial insects rather than introducing exotic species (Gurr, Scarratt, Jacometti & Wratten, 2007). Conservation biological control utilises an approach of habitat manipulation to boost the number of natural predators in an area.

There are several examples of CBC innovations mentioned in literature. Hoddle (2004) noted that many highly successful biological control practices have been implemented against noxious insects, weeds, plant pathogens and vertebrates. In Australia, the addition of lucerne strips within cotton crops has resulted in two effects. Firstly, the green crop mirid pest is attracted to the lucerne rather than the cotton, and secondly, the lucerne attracts natural predators of the mirid pest into the cotton crop (Mensah & Kahn, 1997). Similarly, the planting of mustard strips around the outer edges of sweet corn crops in New Zealand was found to result in the green vegetable bug being attracted to the mustard and thus allowed the sweet corn to reach harvest stage with no significant damage (Rea et al., 2002). A study of the effects of foraging birds on the control of the coffee berry-borer in Jamaica found there was less infestation and berry damage in areas where bird species were present (Kellermann, 2007). Conversely, infestation and berry damage was greater in the areas of coffee plants where birds had been excluded. Whilst this study did not utilise any habitat manipulation techniques, it did report increased predator bird numbers at sites with greater shade cover; this suggests that there is an opportunity to control berry-borer in coffee farms through changes to the habitat in line with the definition of conservation biological control. These studies provide some evidence that CBC innovations have been used successfully to control pests, but scientific innovations are only useful if they are readily adopted by farmers.

In general, the adoption of CBC practices by farmers has been found to be limited (Falconer & Hodge; 2000; Pietola & Lansink, 2001). Sassenrath et al. (2008) noted that the adoption of innovations by farmers is an interaction between a range of external and internal factors, such as political and social pressures and monetary constraints. Whilst there is little doubt that farmers seek increased profitability, they also tend to be risk-averse. The innovations which can reduce production risk and

are relatively simple to establish are those which are most readily adopted by farmers. Griffiths et al. (2008) noted that adoption of CBC practices is influenced by risk perceptions, the efficacy of the innovation, and whether price premiums could be gained in the marketplace as a result. A review of agricultural literature revealed that the adoption of innovations by farmers is generally related to three main factors: the process of learning about the innovation, the relative advantage of the innovation over existing practices, and the ease of innovation trialability (Cullen et al., 2008). Hoddle (2004) suggested that adoption of biological control practices is most often related to a reduction in expenditure for agrichemicals, labour and specialised equipment. Similarly, Shadbolt (2005) reported that labour costs and risk were factors which limited innovation adoption by farmers, whilst the potential for reduced costs, increased yields and marketing benefits were highly motivating factors for CBC implementation in vineyards. A study of New Zealand dairy farmers and their propensity to adopt sustainable management practices provides a summation of the factors frequently mentioned in the adoption literature. Adoption was found to depend primarily upon the farmer's perception of the benefits that would arise, and these related to the commercial and practical realities of the innovation to the farmer (Bewsell & Kaine, 2005). It is clear that any promoted CBC innovation must not only resolve an ecological issue but must also provide other business benefits in order for it to be adopted by farmers.

Whilst several authors have suggested that biological control innovations can result in economic benefits to farmers, any such benefits may be difficult to measure. Dyllick and Hockerts (2002) noted that although the value of ecosystems services is quite considerable, this value isn't necessarily well understood. Gurr, Wratten and Luna (2003) suggested that innovations which increase biodiversity in order to control pests could result in additional benefits such as higher crop yields or improved quality, but that such results would be difficult to demonstrate. Nentwig, Frank and Lethmayer (1998) mentioned that there is limited knowledge of the impact of CBC innovations on agronomic aspects such as crop yield and maintenance practices as well as financial aspects such as farm income. In addition, Rodenhouse et al. (1992) suggested that the use of vegetative biodiversity innovations would help to prevent soil erosion by wind and water, but this effect was not examined. Biocontrol innovations may also result in economic benefits arising from reduced agrichemical use, the attracting of premium prices or increased market share. Fiedler et al. (2008) suggested that aside from pest control, additional benefits such as biodiversity

conservation, ecological restoration and human cultural values could be accrued through the implementation of the habitat manipulation practices common to CBC. The economic impacts of implemented innovations such as increased yield or farm income can be categorised as direct impacts, whilst the impacts that arise from subsequent spending and respending within an economy are categorised as secondary. Griffiths et al. (2008) suggested that CBC techniques could provide benefits to the wider society; such benefits can be thought of as being secondary impacts. This study has examined only the direct impacts resulting from the implemented CBC innovation.

Economic analysis of biological control innovations is not well documented in literature. In their seminal paper, Constanza et al. (1997) suggested that ecosystem services are not fully captured or adequately quantified in traditional economic analysis; they estimated that the value of biological control of pests globally was US\$417 billion per year. Cullen et al. (2008) stated that economic assessments of CBC programs are rarely conducted. One of the few studies to analyse the financial benefits and costs associated with a CBC innovation to control pests was that by Thomas et al. (1991). The study revealed that the cost to establish a beetle bank to control aphids in a 20ha wheat field was US\$130, but the benefits included \$450 from keeping the pest below the threshold level for chemical control and \$1,000 from the avoidance of crop losses. The previously mentioned research on the biological control of berry-borer in Jamaican coffee farms, although not a true CBC innovation, provided evidence that the birds controlled the pest, increased coffee yield and farm income. The economic benefit associated with the biological control of berry-borer, over the control plants, was estimated at an average of \$US75/ha (Kellermann, 2007). In contrast, the findings of Schmidt et al. (2007) revealed that CBC control of soybean aphids was not economically viable. In the study, living alfalfa mulches were used to attract predators to control aphids in soybean crops. Although the innovation successfully reduced the pest population below the threshold level, the alfalfa competed with the soybean crop causing a yield reduction of approximately 26% and therefore was not cost effective for farmers.

The deficiency of published literature which has examined the effect of CBC innovations on business profitability and operations, as well as the results of Schmidt et al. (2007) above, suggest that it is important for further research in this area. This study has asked the following key questions:

1. *What has been the uptake of the CBC innovation by Waipara wine companies?*

2. *What effect has implementation of the CBC innovation had on economic, marketing and operational factors within these companies?*

Method

This study has employed both structured questionnaires to survey multiple respondents, as well as in-depth interviews to provide a case study of two Waipara wine companies. In the first instance, data were collected from vineyards and wineries that were noted as participating in the Greening Waipara Project via self-completed questionnaires. The questionnaires and return postage-paid envelopes were mailed to 32 vineyards and wineries in Waipara in early December 2009. The questionnaire began with general questions that were used to categorise the winery or vineyard operation. Section B examined whether the company had implemented a Biodiversity Trail or had any desire to do so. Respondents indicated which of the innovations they had implemented in Section C of the questionnaire and rated the effectiveness of each implemented innovation using a likert scale. The final section asked each respondent to indicate what impact (i.e. increase, decrease or no effect) each innovation had had on their business in terms of various listed factors (e.g. labour costs, domestic sales, water use, etc). Although a considerable amount of data was collected from the questionnaire, only data pertaining to the CBC innovation is analysed and discussed in this paper.

The second phase of data collection utilised in-depth interviews of staff at two wineries. The two wineries were selected because (1) they had both been members of the Greening Waipara Project for 4 years, (2) they both had implemented Biodiversity Trails and (3) they both sold wine to domestic and export destinations. The major difference between the two wineries was in the size of their operations; one winery consists of just 1 hectare of 'home' vineyard and has annual wine sales of less than 200,000 litres, whilst the other winery has 20 hectares of 'home' vineyard (plus a further 430 hectares planted through the Valley) and wine sales in the category of 200,000 to 4,000,000 litres annually. The larger of the two wineries had implemented the CBC innovation to control leafrollers, whilst the smaller property had not.

A total of fourteen companies responded to the survey, resulting in a response rate of 44 percent. Five of the fourteen properties in the sample were vineyards without attached wineries; of the nine wineries, eight had annual sales of less than 200,000 litres. The sampled wineries thus reflect the nature of the New Zealand wine industry, which is comprised predominantly of small producers.

Results

Table 1 indicates that only two of the fourteen companies that responded to the survey had implemented the CBC innovation to control leafrollers. In terms of the effectiveness of the CBC innovation, one respondent rated the practice as ineffective, whilst the other respondent evaluated it as being somewhat effective (see Table 1 attached).

Table 2 illustrates the impact (i.e. increase, no effect or decrease) that the CBC innovation has had on various economic, marketing and operational factors at the two companies. (see attached).

Analysis from the interview with the wine company which had implemented the CBC innovation exposed the reality of the innovation at an operational level. In the interview with the company's viticulturist it was revealed that this company previously had large numbers of leafrollers in their vineyard but they did not cause a major problem in terms of resulting *Botrytis* damage because of the typically dry climate in Waipara. The company had previously sprayed their vineyard at least once per season with an insecticide to reduce leafroller numbers. The CBC innovation introduced by the Greening Waipara Project has seen the company plant inter-rows with buckwheat in order to attract parasitoid wasps. Since adopting this innovation, the company no longer sprays to control leafrollers and the viticulturist said that they are no longer highly visible in the vineyard.

Whilst the cost of buckwheat seed is quite low (NZ\$1.50/kg), the viticulturist reported that it had trebled in price over the past couple of years and was in short supply this past season. The company applies herbicide on the inter-rows before planting to control weeds. Every sixth row of the vineyard is planted with buckwheat. The initial plantings are done as a two-stage process, with the first planting on every twelfth row in early October and a second planting in early November to complete the sowing of buckwheat in every sixth row. This staggered planting helps to prolong the flowering period of the buckwheat across the vineyard. However, the initial plantings do not flower for the entire season, so third and fourth sowings of buckwheat seeds are made in the same rows at a later date. The company employs a practice of cutting the buckwheat part way through the season in order to prolong the flowering cycle of the plants. The viticulturist noted that it is sometimes difficult to fit in the establishment of the buckwheat rows and the maintenance mowing during what is a busy time in the vineyard. Aside from the labour and seed costs, the planting of buckwheat also requires the use of machinery such as a roller and a seed driller, which are not equipment that a vineyard would typically own. The other major issue the viticulturist faced is that the vineyard inter-rows are not an irrigated

area. For this reason, the buckwheat seeds must be sown at a time when rainfall is due in order to aid germination and crop establishment. As mentioned, Waipara is a very dry region and the viticulturist noted that some sowings have not been too successful because of dry weather. The viticulturist believed that cost-wise the conventional spraying and the CBC innovation was similar, but he did state that chemical spraying is a lot easier to do. The company had decided to implement the CBC innovation because they wanted to adopt ecologically healthier practices and to reduce intervention in the vineyard; they were not motivated by any economic factors.

Discussion

The results illustrated in Table 1 indicate that the uptake of the CBC innovation across Waipara wine companies has been very low. This study did not seek to ascertain the reasons behind non-adoption of the CBC innovation, but it could be surmised in line with the reported literature that farmers may have viewed the innovation as being of greater risk to yield and profitability than the conventional use of insecticides. As mentioned in the case study, one aspect of risk in the Waipara region is the dry climate which can limit the establishment of the inter-row crops. Sassenrath et al. (2008) suggested that agricultural innovations which reduced risk and were simple to establish were most readily adopted by farmers; Waipara wine companies may have felt that the CBC innovation posed a risk to yield or was too difficult to establish. The interview with the company which had adopted the innovation provides support for the idea that the innovation is quite difficult to establish and maintain and is not as easy to do as conventional agrichemical pest control. Hoddle (2004) noted that farmers may adopt biological control practices if they result in reduced costs for agrichemicals, labour and specialised equipment. In the case of this CBC innovation, agrichemical costs have been reduced, but the labour and specialised equipment costs have increased. It is likely that a combination of risk, financial and establishment factors are responsible for the low uptake of the CBC innovation among Waipara wine companies.

The respondents' ratings of the effectiveness of the implemented innovation are also of concern. The reasons behind these ratings may be explained by the results that are illustrated in Table 2.

The implemented CBC innovation had no effect on the companies in terms of many of the listed economic, business or marketing factors (see Table 2). From an economic perspective, one of the two respondents noted that the CBC innovation has resulted in increased labour and vineyard floor management costs; the other company noted no change in these costs. The case study certainly

provided support for the notion that labour and vineyard floor management costs would rise. The processes involved in establishing, maintaining and re-establishing the inter-row crops over a season are quite clearly labour intensive and also incur the costs of herbicide, seed and additional machinery purchases. On a positive note, both companies stated that implementation of the innovation had reduced their agrichemical costs. This result was backed up by the comments of the viticulturist who said that high numbers of leafrollers were no longer visible in the vineyard since the CBC innovation had been adopted. This result certainly provides evidence that from an ecological standpoint, the CBC innovation has successfully reduced leafroller numbers.

In terms of marketing, neither company has benefited from the innovation in terms of important aspects such as the wine price, consumer demand, cellar door sales, domestic sales, or international sales. One of the two companies noted that the innovation had increased their access into new domestic and international markets. The increased access to markets probably relates to the environmental focus which major global retailers are increasingly adopting and the demands that they are placing upon their food and beverage suppliers. Whilst some companies have added a comment about the innovations on the back label of their bottles, it should be noted that there is no standardised Greening Waipara symbol or logo that companies can stick to their front labels. The lack of marketing benefits to arise from the innovations is thus probably attributable to poor consumer awareness and recognition, particularly in international markets.

From an operational perspective, the innovation hasn't had any effect on either wine quality or yield per hectare. This result does not provide support for the suggestion from earlier researchers that CBC innovations could result in yield and quality improvements (Gurr, Wratten & Luna, 2003). Similarly, whilst Rodenhouse et al. (1992) suggested that soil erosion could be decreased through vegetative biodiversity innovations, one company noted that the innovation had actually increased the level of soil erosion. The company which has noted an increased level of soil erosion with the CBC innovation is possibly comparing the establishment and maintenance of the inter-row crop with an alternative grassed inter-row. Having plants down the inter-row will obviously reduce soil erosion, but the process to establish and maintain the buckwheat may increase soil loss. Similarly, having bare inter-rows through the cold season will also have a detrimental impact on the level of soil erosion.

Conclusions

There is little doubt that our intensively managed agricultural landscape has resulted in the disappearance or endangerment of many original species. Adoption of a CBC approach to control pest populations can result in more sustainable agriculture, a reduction in the use of agrichemicals and an enhancement of ecosystems. The findings reported in this paper have provided evidence that the use of inter-row crops in vineyards can result in the biological control of leafrollers and a reduction in agrichemical usage. However, the uptake of this innovation is low amongst winegrowing companies and their overall evaluation of the innovation is quite poor. This suggests that the innovation, although ecologically successful, may not be sustainable at an economic, marketing or operational level. Cullen et al. (2008) noted that farmers must perceive biological pest control innovations to have economic advantages at an acceptable level of risk when compared to the relatively simple conventional agrichemical control methods. The key finding of this paper is that biological control innovations must be developed in a manner which gives consideration to the realities at the farm level.

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Table 1. Implementation of the CBC Innovation (number of responses)

Innovation	Not Implemented	Implemented			Unsure
		Ineffective	Somewhat effective	Very effective	
Inter-row plantings to prevent leaf rollers	12	1	1		

Table 2 illustrates the impact (i.e. increase, no effect or decrease) that the CBC innovation has had on various economic, marketing and operational factors at the two companies.

Table 2. Business Impact of Implemented CBC Innovation (number of responses)

	Inter-row plantings to prevent leaf rollers		
	Increase	No effect	Decrease
Cost of labour	1	1	
Cost of agrichemicals			2
Cost of vineyard floor management	1	1	
Cost to maintain implemented practices		2	
Wine price		2	
Customer demand		2	
Advertising / promotions expenditure		2	
Cellar door sales		2	
Domestic sales		2	
International sales		2	
Access into new domestic markets	1	1	
Access into new international markets	1	1	
Communication with Waipara wineries		2	
Communication with Waipara vineyards	1	1	
Need for vineyard bird control		2	
Need for vineyard pest control		1	1
Level of vineyard soil erosion	1	1	
Level of water use (irrigation)		2	
Grape quality		2	
Wine quality		2	
Yield per hectare		2	