

A Survey to Evaluate the Long-term Relationship Between *Chrysolina quadrigemina* and its Host-weed, St. John's Wort, in Southeastern Australia

D.T. Briese

CSIRO Division of Entomology, G.P.O. Box 1700, Canberra, A.C.T. 2601, Australia.

Abstract

The design and setting up of a long-term survey to evaluate the overall impact of *Chrysolina quadrigemina* on St. John's wort is described. Information is being gathered by questionnaire three times/yr from 108 sites throughout the range of the weed in southeastern Australia. This data covers: (1) details of the St. John's wort infestation; (2) the size of *C. quadrigemina* populations and damage caused by them; and (3) management practices used at the site. Data of climatic and physical variables are also being obtained. Some early results are shown. Preliminary analyses of these indicate that the survey will be able to quantify geographic and temporal trends in the interaction between *C. quadrigemina* and St. John's wort. In addition, they show that it should be possible to identify factors which modify this interaction.

Évaluation des Relations à Long Terme Entre *Chrysolina quadrigemina* et la Plant Nuisible Hôte, le Millepertuis Perforé, dans le Sud-est de l'Australie

Le rapport traite de la conception et de l'organisation d'une étude à long terme destinée à évaluer les effets globaux de *Chrysolina quadrigemina* sur le millepertuis perforé. Des questionnaires sont distribués trois fois l'an dans 108 sites de l'aire de répartition de cette plant nuisible dans le sud-est de l'Australie. Les questionnaires portent sur: (1) le degré d'infestation du millepertuis perforé; (2) la taille des populations de *C. quadrigemina* et leurs effets sur la plant nuisible; et (3) les techniques de gestion employées sur le site. On rassemble aussi les données sur les paramètres climatiques et physiques. Le rapport présente certains résultats préliminaires. Les premières analyses ont révélé qu'il sera possible de quantifier les tendances spatiales et temporelles de l'interaction entre l'agent biologique et la plant nuisible. En outre, d'après cette analyse, il devrait être possible la reconnaître les facteurs qui modifient cette interaction.

Introduction

The aim of introducing biological control agents is to bring about a reduction in the population of the target weed to a lower equilibrium density, below that of its economic threshold (van den Bosch *et al.* 1973) (Fig. 1a). Unfortunately, as Harris (1981a) has pointed out, many agents, although they may establish, do not have this effect. Species may stabilize at low population levels which have little impact on weed density (Fig. 1b), or their population density may fluctuate widely, resulting in reductions of the target weed which may not be maintained (Fig. 1c). Agents which show such partial success are, however, an important component of control procedures against particular weeds, for they contribute to the stress load on the plant (Harris 1981b). Therefore, it is desirable to assess the impact of such an agent to understand how it might interact with additional stress factors (e.g. grazing pressure, plant

competition, drought, the introduction of additional biological control agents and the use of herbicides) which might lead to more effective control of the weed.

Given time, such agents are likely to have colonized a range of habitats containing the weed, and their impact may vary markedly between localities as well as with time.

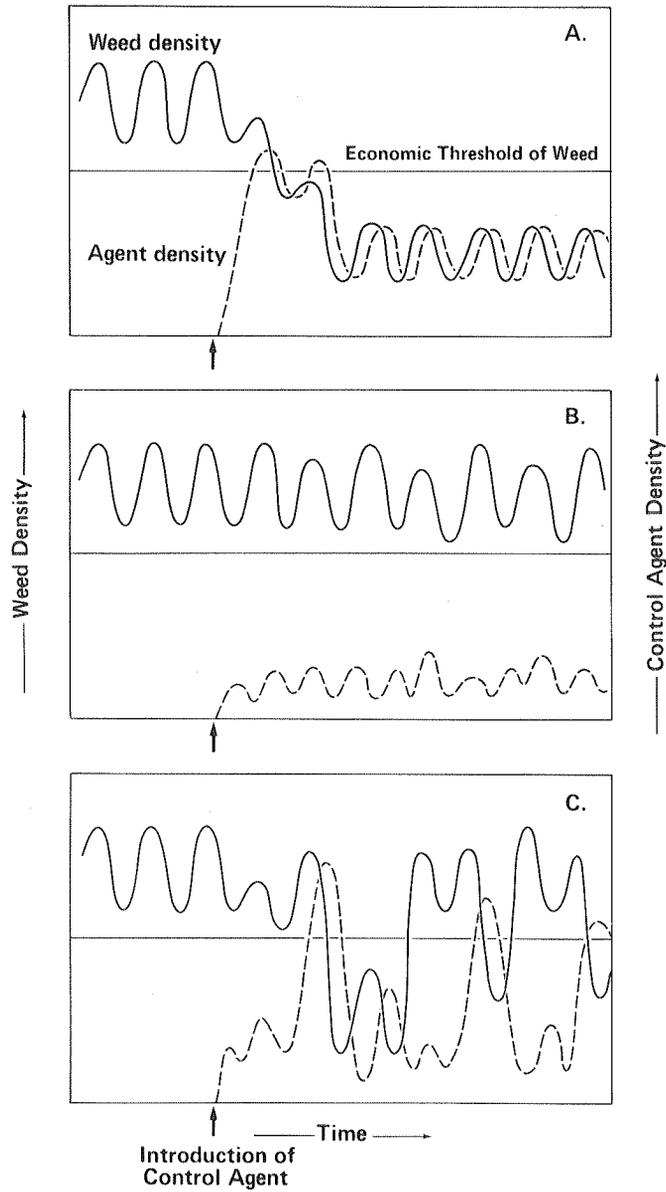


Fig. 1. Expected relationship between the densities of weed and control agent: (A) when the agent successfully controls the weed; (B) when the agent survives at low levels but does not significantly reduce weed levels; and (C) when agent populations fluctuate widely, giving partial or unstable control.

Thus, there will exist a complex set of relationships which make an overall evaluation of the agent a difficult task. Such a study would require the collection of data over a wide area and over a long period of time, an exercise which could have serious logistic

and financial constraints. One possible solution would be to organize a survey network where data can be collected by individuals at diverse localities and collated at a central point. If the collection of the data were kept simple it could be carried out routinely over an extended period with minimal cost in time or money.

This paper outlines the design of such a long-term survey to evaluate the overall impact of *Chrysolina quadrigemina* Suffr. (Coleoptera: Chrysomelidae), a defoliating beetle which has shown partial success against St. John's wort (*Hypericum perforatum* L.; Clusiaceae) in southeastern Australia.

The *Chrysolina*-St. John's Wort System in Southeastern Australia

C. quadrigemina was first released in northeastern Victoria in 1939. Larvae and adults defoliate St. John's wort, in winter and spring respectively, and initially the species showed great promise and contributed to the successful control of the weed in certain areas near the original release site (Wilson 1960). This led to a massive redistribution program which continued intermittently until the mid-1960s. As a result, *C. quadrigemina* is presently found through most of the range of its host weed (Fig. 2), and has coexisted with its host plant in most locations for 20-45 yrs. It does not yet occur in some areas to which St. John's wort has recently spread, such as western Victoria (Shepherd 1983).

Detailed evaluation studies undertaken a few years after establishment (Clark and Clark 1952; L.R. Clark 1953; N. Clark 1953) clearly demonstrated the limitations of *C. quadrigemina* in exercising effective control, by itself, over St. John's wort: its inability to colonize timbered areas, its slow rate of increase, and most importantly, the ability of St. John's wort infestations to regenerate following defoliation in the absence of other stress. This latter point was further emphasized by Huffaker (1966), who found that substantial summer rainfall, typical of many of the St. John's wort-infested areas of Australia, could promote regeneration following defoliation as well as upsetting the synchrony of reproduction and development in the beetles (*C. quadrigemina* adults undergo obligate aestivation over summer, which is broken by autumn rains prior to oviposition). Notwithstanding the above, Huffaker (1966) felt that *C. quadrigemina* provided sufficient additional stress on St. John's wort to make it an important factor in the control of the weed. He cited areas in northeastern Victoria where reclamation of large tracts of St. John's wort-infested land was attributed to the beetle. Since Huffaker's study, further reports of large infestations of St. John's wort being controlled by *C. quadrigemina* have been made for areas with predominantly summer rainfall, notably Mudgee, N.S.W., in the late 1960s (W. Ryan, pers. comm., 1982) and the Liverpool Ranges, N.S.W., between 1978-82 (I.R. Arnott and A. McMaster, pers. comm., 1982).

More typically though, *C. quadrigemina* behaves either as in Fig. 1b, in that populations of the beetle never reach levels which inflict significant reductions of infestation size, or as in Fig. 1c, in that populations periodically increase to damaging levels, but do not normally affect a lasting reduction in weed density. Because of this the beetle has generally been perceived as a failure in areas of high summer rainfall and in forested country. This led to a revival of the biological control program against St. John's wort by CSIRO Division of Entomology in 1979 (Delfosse and Cullen 1981).

This program involves the introduction of new control agents, such as the geometrid defoliator, *Anaitis efformata* Guenée (Lepidoptera: Geometridae), which is currently being released (Briese, unpubl. data). An established species such as *C. quadrigemina*, which is capable of periodically causing extensive defoliation, will have an important

bearing on the success or failure of subsequent agents. For example, in the 1940s a colony of the root-borer, *Agrilus hyperici* (Creutzer) (Coleoptera: Buprestidae), was developing well in northeastern Victoria until the release area was repeatedly defoliated by waves of *C. quadrigemina* adults (T.G. Campbell, unpubl. data), and recent studies have shown that the autumn generation of *A. efformata* can be detrimentally affected when *C. quadrigemina* larvae defoliate St. John's wort (Briese, unpubl. data). Thus it is important to obtain information on the frequency and extent of such events, the factors that might contribute to their occurrence, and whether they are predictable.

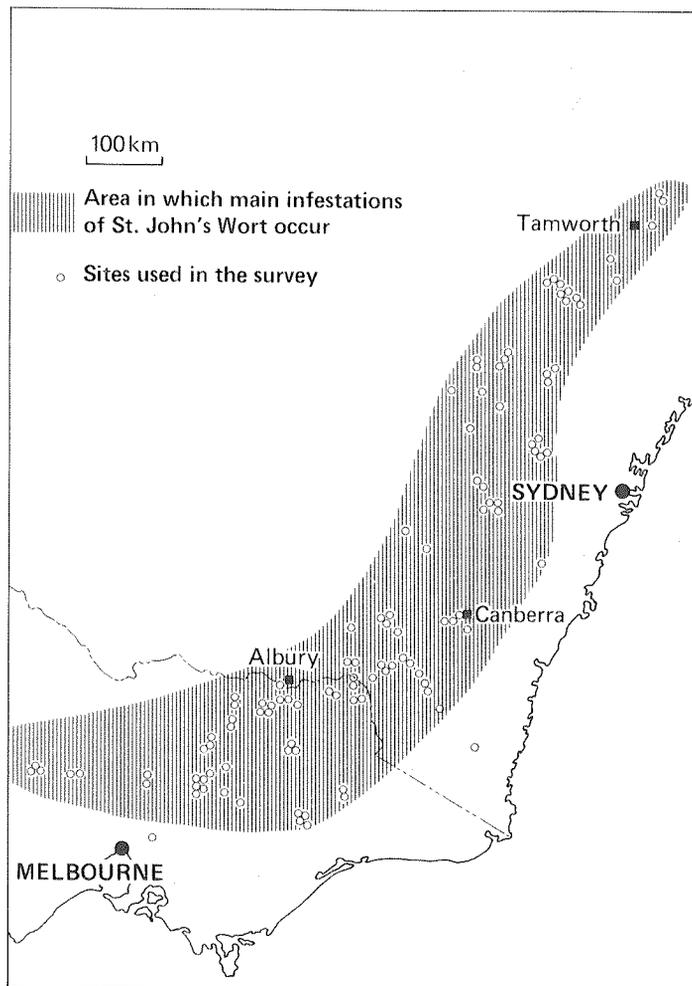


Fig. 2. Distribution of sites being used in the survey of the relationship between *Chrysolina quadrigemina* Suffr. and St. John's wort, *Hypericum perforatum* L., in southeastern Australia.

Moreover, in this program *C. quadrigemina* is being viewed as a contributory stress factor, as suggested by Huffaker (1966), rather than as a solution in itself. Thus it becomes important to understand the overall impact of the beetle. While earlier evaluation studies provided some answers, they were restricted to relatively short periods or to a few specific locations. It is hoped that by obtaining information on long-term changes and regional differences in both *C. quadrigemina* and St. John's wort

populations, we might better understand what contributory stress factors are involved when the beetle is 'successful' and how the effect of the beetle might be best complemented. The success of a previous questionnaire survey in delineating the area of distribution of *Chrysolina* spp. and St. John's wort in Victoria (Shepherd 1983) offers promise that this more ambitious project will produce useful results.

Design of the Survey

The survey network consists of 108 sites throughout the range of St. John's wort infestations in mainland southeastern Australia (Fig. 2). One of the more important requirements of such a survey was to enlist observers with sufficient experience to ensure reliability of the data collected. This was provided by the help of State government Land Inspectors in Victoria and local government Noxious Weeds Inspectors in New South Wales. In addition, some private landholders, who had been particularly troubled by St. John's wort and who were interested in the biological control program, are taking part in the survey. In all, the 108 sites are being monitored by 39 observers (Table 1; see also Appendix 1).

Table 1. Summary of observers participating in the survey on long-term relationships between *Chrysolina quadrigemina* Suffr. and St. John's wort, *Hypericum perforatum* L.

Status of observer	No. of observers	No. of sites
Inspector of Lands (State Government)	16	47
Noxious Weeds Inspector (Local Government)	15	37
Private Landholder	5	11
Entomologist (Federal Government)	2	10
National Park Ranger	1	3
TOTAL	39	108

Some of the sites were chosen by CSIRO officers, including four in which regular, detailed observations on *C. quadrigemina* and St. John's wort population dynamics are being made. The majority, however, were chosen by the observers, who had been asked to select sites which were 'typical' areas of infestation in their respective districts or properties. Thus sites were not chosen because they carried particularly dense or intractable infestations, nor was the presence or absence of *C. quadrigemina* a criterion. Rather, they represented a range of the conditions under which St. John's wort was considered a problem weed. Furthermore, no conditions were placed on the subsequent usage or treatment of sites since it was intended to study the impact of the beetle under normal management practices. Prior to the start of the survey virtually all sites were visited by CSIRO officers to ensure their suitability and to brief observers on the aims and requirements of the survey. The collection of data commenced in the spring of 1982, although some information concerning events in the winter of 1982 had been obtained during the above-mentioned visits.

The survey consists of three separate questionnaires which are sent out to observers at those times of the year which are critical to the life cycle of *C. quadrigemina*: autumn, when adults emerge from aestivation to mate and commence oviposition; winter, when larvae feed on the prostrate growth of St. John's wort; and spring, when new adults emerge and feed on the upright flowering stems. No data is sought in summer when adult beetles aestivate.

The questionnaires seek information in three areas: (1) details of the St. John's wort infestation; (2) the size of *C. quadrigemina* populations and damage caused by them; and (3) management practices used at the site. In addition, information on climatic and physical variables that possibly influence the system is being obtained from other sources (Table 2). Some fine tuning of the questionnaire format, including the addition of some extra questions, was made during the first few surveys. The final format is shown in Appendix 2.

Table 2. Types of data being collected in the survey on the long-term relationship between *Chrysolina quadrigemina* Suffr. and St. John's wort, *Hypericum perforatum* L. in southeastern Australia.

Data Collected	Form of Data	Rating Scale
A. Details of the St. John's wort infestation		
1. Size of infestation being observed	quantitative	n.a.
2. Density	semi-quantitative	1-3
3. Change in density or size from previous year	semi-quantitative	-2 to +2
4. Plant vigour	semi-quantitative	0-10
5. Extent of infestation beyond plot borders	qualitative	n.a.
6. Amount of tree cover	semi-quantitative	0-2
B. Details of <i>C. quadrigemina</i> population and damage caused.		
1. Presence of various life stages in autumn	presence/absence	0 or 1
2. Combined population density/damage rating of adults in spring	semi-quantitative	0-5
3. Combined population density/damage rating of larvae in winter	semi-quantitative	0-5
4. Degree of plant regeneration following defoliation	semi-quantitative	0-10
C. Management practices		
1. Other methods of control used	qualitative	n.a.
2. Grazing pressure and type of stock	qualitative	n.a.
3. Density of other vegetation	semi-quantitative	1-3
D. Other factors potentially important to the system.		
1. Rainfall	quantitative	n.a.
2. Temperature	quantitative	n.a.
3. Soil type	qualitative	n.a.
4. Site position (aspect and slope)	qualitative	n.a.

With regard to the data sought by questionnaire, the observers are asked to indicate which of a number of rating levels or categories best fit the particular sites, using a 'tick the appropriate box' format (see Appendix 2). *C. quadrigemina* is particularly suited to such a system, for the high visibility of adult beetles and of the damage caused by adults and by larvae means that rating levels could be defined which are readily distinguishable. For example, six such categories are used in the critical measurements of beetle population density/damage, ranging from 0 (when *C. quadrigemina* could not be found) to 5 (when large feeding fronts defoliated the entire survey plot) (see Appendix

2). These levels are relative to the density of St. John's wort at each site, so that differences in density of the weed between sites are accommodated in the data.

The questionnaires produce a set of semi-quantitative and qualitative data for each site which can readily be encoded onto computer files. This system was preferred to obtaining more exact quantitative data for several reasons. First, it would have been unfair to expect the observers to devote large amounts of time to the collection of this data, when they had undertaken to carry it out in the course of their normal duties. Second, when such a diverse group of people are carrying out measurements, one could not expect that detailed data would be comparable. Third, although the forms were sent out at one time, the actual times of data collection could vary by several weeks between sites, which would again make comparisons of exact information unreliable. The semi-quantitative rating system sacrifices detail for consistency and comparability, since differences between rating levels are sufficient to accommodate variations due to differences between observers and between the times of observation.

Between 94 and 96% of forms have been returned at each survey period. To help maintain interest in the exercise and a high rate of returns, summaries of the data collected during each observation period are produced and forwarded to the observers with the next set of questionnaires. This also provides feedback which may be of some value to the observers in their own work programs.

Early Results

In a survey where data are collected mainly in a semi-quantitative form, it is important to examine the early returns before becoming committed to long-term involvement, to see whether information collected in this manner is amenable to analysis and likely to provide answers to the questions posed.

As indicated in the previous section, the purpose of this survey is twofold: first, to determine the frequency and extent of damaging outbreaks of *C. quadrigemina*; and second, to determine the underlying factors and contributory stresses associated with these events. Although data have only been collected for 2 yrs, early returns indicate that it will be possible to estimate the temporal and spatial patterns of *C. quadrigemina* populations and their impact on St. John's wort. Fig. 3 shows the distribution and frequency of *C. quadrigemina* damage ratings in spring 1982. This was a period of severe drought in southeastern Australia, and the majority of sites (69%) supported low *C. quadrigemina* population levels, which did not cause significant damage to St. John's wort. Only 11% of sites supported damaging population levels of *C. quadrigemina* and these occurred mainly in that part of the weed's range where winter rains are predominant (Fig. 3). A breakdown of data from other survey periods indicate that this pattern, in which *C. quadrigemina* is present at most sites but is ineffective, has persisted (Fig. 4). Furthermore, significantly more sites in the winter rainfall zone than elsewhere reported damaging population levels of the beetle (20.9 vs. 10.4% $t_{404} = 7.0$, $P < 0.01$) over all survey periods. This reflects the traditional view that the beetles are less successful in the northern areas where summer rainfall is more important.

Ultimately, the survey will generate a series of profiles showing temporal changes at each site. Fig. 5 provides examples of such profiles, which will eventually include other factors listed in Table 2. They are from two sites in N.S.W. where successful control of St. John's wort has been attributed to *C. quadrigemina* (Coolah Creek and Cassilis) and from four sites where CSIRO is undertaking more detailed studies. A longer period of records was available for these locations. The profiles show how

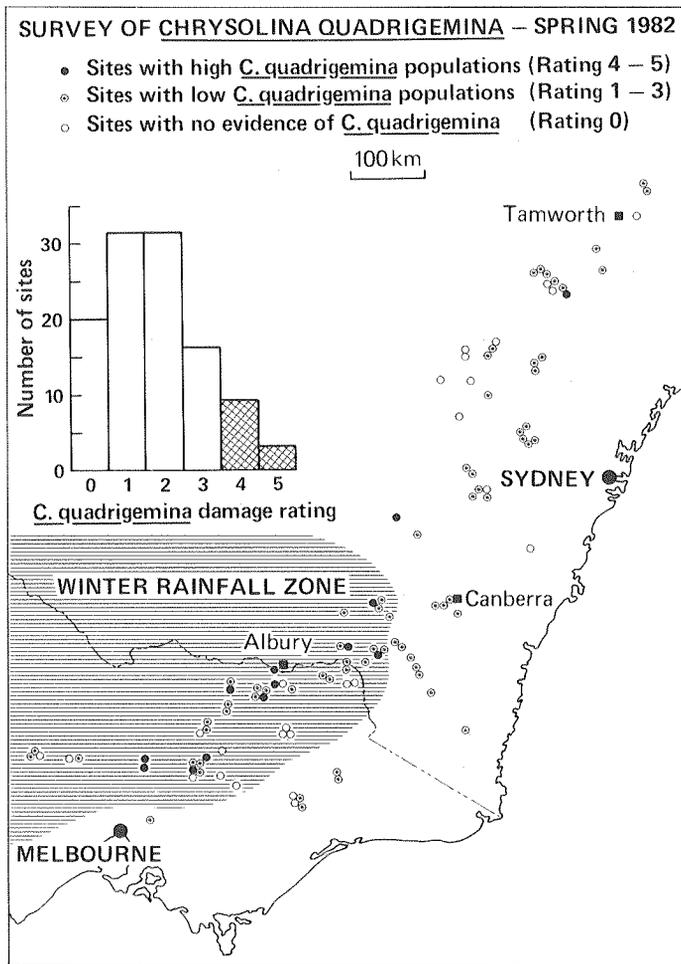


Fig. 3. Pattern and frequency of *Chrysolina quadrigemina* Suffr. populations and associated damage ratings during the spring 1982 survey.

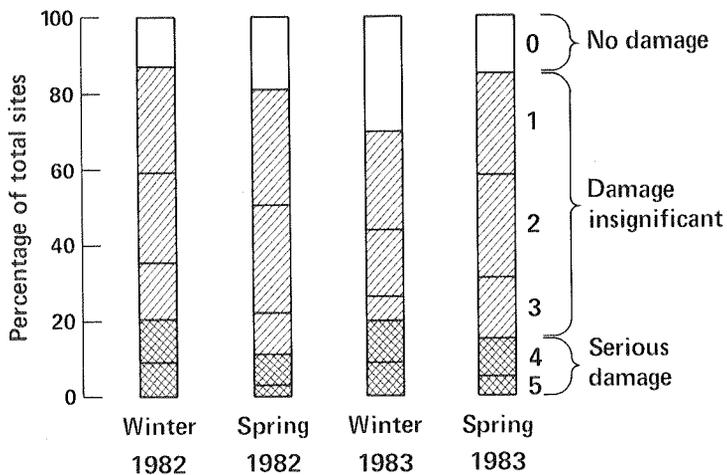


Fig. 4. Percent of sites showing different damage ratings for *Chrysolina quadrigemina* Suffr. over four survey periods.

increases in beetle populations have led to extended declines in the density of St. John's wort at the Coolah Creek and Cassilis sites, followed by a decline in beetle numbers, and finally a resurgence of the weed in 1983 after the breaking of a severe drought. A similar pattern of increase and decline in the beetle population was apparent at Pierce's Creek, but at this site the reduction in St. John's wort density was very transient (Fig. 5). These three sites exhibit the relationship between control agent and host weed shown in Fig. 1c. The remaining three sites (Fig. 5) show relationships typical of Fig. 1b, in that beetle populations have remained relatively low and have not significantly affected the density of the host weed.

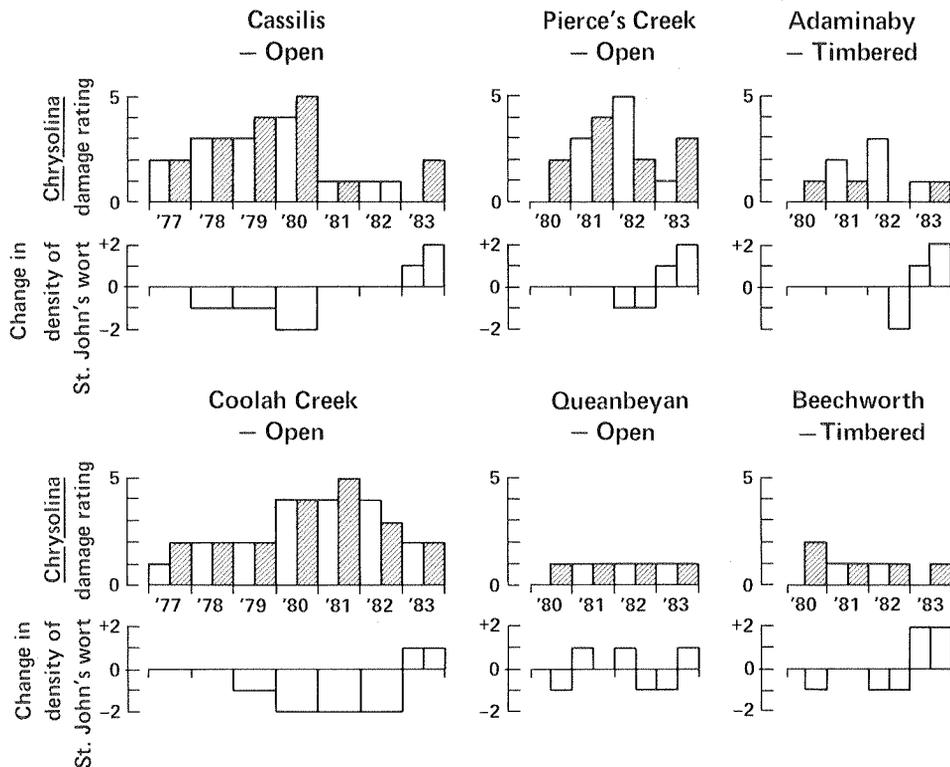


Fig. 5. Temporal patterns of: (a) the damage rating for *Chrysolina quadrigemina* Suffr.; and (b) the change in density of St. John's wort, *Hypericum perforatum* L. at selected sites in southeastern Australia.

The role of contributory factors in the decline of St. John's wort at some sites will have to await the availability of more data. However, the role of the extended drought period from 1980–82 obviously has had some influence. As only a small body of data is available, preliminary analyses have been restricted to the two factors which were considered of prime importance in the revival of the biological control program, namely tree cover and rainfall pattern (Delfosse and Cullen 1981). These suggested that the data being obtained should be able to provide information on the effects of contributory factors.

A comparison of the frequencies of the various damage ratings over all survey periods in 1982–83 showed significant heterogeneity between open sites and those having some tree cover ($X^2_{10} = 37.8$, $P < 0.01$). This was due to the greater incidence of damaging populations in open areas of both larvae in winter and adults in spring (Fig. 6). Such

a result was not unexpected, as the aversion of *C. quadrigemina* to heavily shaded areas is well-documented (L.R. Clark 1953). What is important for the survey is that the result indicates that data obtained by a semi-quantitative rating system is capable of identifying such modifying factors.

The proportion of sites with tree cover did not differ significantly between rainfall zones, and therefore did not contribute to the regional differences in the incidence of damaging population levels of *C. quadrigemina* noted earlier. To determine whether rainfall pattern could have influenced this pattern, a series of correlation coefficients and partial correlation coefficients were calculated for several pairs of parameters (Table 3). As one cannot make claims for cause and effect from correlations without corroborating evidence, the following interpretation has been tentatively made, based on information on the biology of *C. quadrigemina* obtained by L.R. Clark (1953).

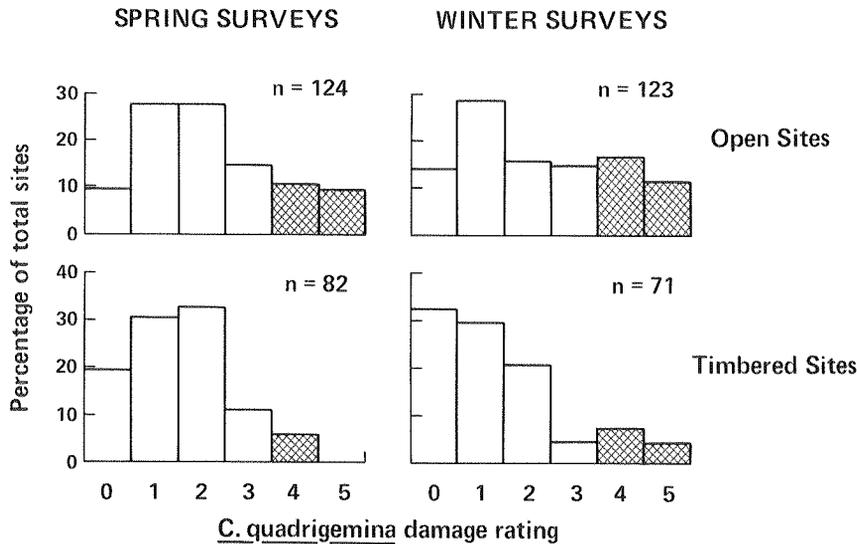


Fig. 6. Influence of tree cover on the frequencies of sites showing different damage ratings for *Chrysolina quadrigemina* Suffr. (hatched bars indicate serious damage).

The occurrence of high population densities of adult *C. quadrigemina* was correlated to winter rainfall in the drought year of 1982–83 and when rains were generally above average in 1983–84 (correlation 1, Table 3). Winter rains promote the growth of procumbent stems of St. John's wort, which provides sufficient food to support a large population of larvae. They also promote the growth of other vegetation which, together with St. John's wort, provides essential shelter for the larvae (L.R. Clark 1953). There was a stronger correlation between larval population density and winter rainfall during 1983–84 than in the preceding drought year (correlation 2, Table 3). Nonetheless, larval populations were able to reduce significantly the density of the weed under drought conditions and when winter rain was favourable (correlation 3, Table 3). Following the onset of above average rainfall during 1983–84 there was a widespread resurgence of St. John's wort, which resulted in a lack of correlation between weed density and winter rainfall for this period, whereas in the preceding year, drought stress over winter had contributed to the reduction of St. John's wort (correlation 4, Table 3). Larvae at more severely drought-stressed sites tended to defoliate the plants more rapidly because of the poor growth, leading to a negative correlation between rainfall and the larval

damage rating (correlation 2, Table 3). However, this caused a reduction in food and shelter and subsequent adult populations were greatly reduced at these sites. This explains the much better correlation between adult density and winter rainfall than between larval density and winter rainfall in 1982–83 (Table 3). Thus, while winter drought may favour the control of St. John's wort in the short-term, in the long-term it inhibits the build-up of beetles to damaging levels.

Large populations of adults were also able to reduce the density of St. John's wort (correlation 5, Table 3), although the modifying effect of summer rainfall on the impact of adults (Huffaker 1966) was apparent (correlation 6, Table 3). At most sites high proportions of defoliated plants (up to 90%) recovered when summer rains fell following attack by *C. quadrigemina*.

Table 3. Correlation coefficients between parameters measuring changes in St. John's wort, *Hypericum perforatum* L., density, *Chrysolina quadrigemina* Suffr. damage ratings and rainfall.

Parameters	Correlation Coefficients	
	1982-83 (Drought year)	1983-84 (Above average rainfall)
1. Winter rainfall ¹ (a) vs. spring damage rating (d)	$r_{ad} = 0.33^{**}$	$r_{ad} = 0.25^*$
2. Winter rainfall (a) vs. winter damage rating for larvae (c)	$r_{ac} = -0.10n.s.$	$r_{ac} = 0.24^*$
3. Winter damage ratings vs. subsequent change for larvae (c) in weed density (e) (winter rainfall held constant)	$r_{ce'a} = -0.49^{**}$	$r_{ca} = -0.38^{**}$
4. Winter rainfall (a) vs. subsequent change in weed density (e) (larval damage rating held constant)	$r_{ac'e} = 0.27^*$	$r_{ae'c} = 0.01n.s.$
5. Spring damage rating vs. subsequent change in: for adults (d) weed density (f)	$r_{df} = -0.37^{**}$	Not available
6. Summer rainfall ¹ (b) vs. subsequent change in weed density (f)	$r_{bf} = 0.25^*$	Not available

* Significant at 5% level, ** significant at 1% level.

¹ Winter rainfall measured between April and September, when *C. quadrigemina* larvae are present and St. John's wort procumbent foliage is growing. Summer rainfall measured between November and January, a period critical for the survival of defoliated St. John's wort plants.

Thus the survey data confirms earlier findings on the influence of rainfall patterns on the *C. quadrigemina*–St. John's wort relationship. Moreover, they emphasize the importance of adequate winter rainfall for the success of the beetle. All sites may receive substantial summer rainfall (averages for December–February range from 102–277 mm). Therefore the risk of regeneration of the weed or of upsetting the synchrony of development in the beetle through summer rains stimulating premature emergence from aestivation is present at all sites. Thus, while the higher incidence of summer rainfall may contribute to the generally low success rate of *C. quadrigemina* in southeastern Australia (Huffaker 1966), the regional differences pointed out earlier may be more an effect of differences in the absolute levels of winter rainfall received.

Finally, it is obvious from the low values of the correlation coefficients that the other factors listed in Table 2 (e.g. grazing pressure, management practice, soil type, vegetation density, etc.) are all contributing to the patterns obtained. The analyses used so far have been very simple. When the survey is completed, the data will be subjected to more sophisticated statistical treatments which should make it possible to indicate which of these other factors are influencing the relationship between *C. quadrigemina* and St. John's wort.

Conclusions

Preliminary analyses of the data indicate that the survey will be able to quantify geographic and temporal trends in the population dynamics of *C. quadrigemina* and St. John's wort, and consequently should be able to answer questions pertinent to the ability of the beetle to control St. John's wort, such as:

1. Are there really regional differences in the impact of *C. quadrigemina* and if so, what are they?
2. Do population cycles of *C. quadrigemina* occur in a periodic or haphazard manner?
3. Is there a general overriding pattern in the impact of *C. quadrigemina*; i.e. is there, as some people suggest, such a thing as a 'good *Chrysolina* year'?
4. What type of fluctuations are there in St. John's wort populations independent of *C. quadrigemina* activity?

The survey should produce a solid body of such information, which in hindsight would have been desirable before any new initiatives in the biological control of St. John's wort were undertaken. However, the data being presently obtained can still serve to guide the development of such programs, rather than relying upon what has largely been an oral history of the species. While it may prove more difficult to determine which contributing factors are important at each site, the preliminary analyses indicate that it is possible. Huffaker (1966) pointed out that the complexity of factors involved makes it very hazardous to try and predict the outcome of *C. quadrigemina* activity at any particular site. The results of this survey should enable such predictions to be made with more confidence.

Finally, as indicated in the introduction, a subsidiary aim of this exercise has been to determine whether surveys such as this might be of general use in evaluating the impact of partially successful biological control agents. In this regard, perhaps the most important result is that data collected in a semi-quantitative form can detect patterns and pinpoint factors that may influence the interaction between agent and weed. Obviously, the use of long-term survey data for any particular agent-weed interaction would have to be considered on its individual merits, but some generalities can be made.

Firstly, if rating systems are employed they will detect only relatively large differences in the various parameters. Consequently, their use would be most relevant for species that respond as in Fig. 1c, such as *C. quadrigemina*. Secondly, since the survey relies on 'non-expert' help and is not intended to be labour-intensive, the species in question would need to be highly visible, or else inflict damage that was fairly obvious. Insect defoliators, gall-formers and fungal pathogens are such groups of agents, whereas agents which are less visible or inflict more subtle damage, such as stem-borers, root-hair feeders and sap-suckers, might be less amenable to the development of rating categories, especially if they did not show large population fluctuations. More detailed data could perhaps be collected for such species, but this leads to a trade-off between effort and expertise required and time and money available.

Within these limitations such surveys could provide a relatively cheap and efficient way of obtaining essential information about certain control agent-weed interactions.

Acknowledgments

I would like to thank the people listed in Appendix 1 who have acted as observers for this survey. Permission for officers of the Victorian State Government to participate was given by the Department of Crown Lands and Survey. Thanks are also due to K.R. Pullen who helped to set up the survey, and Dr. R. Morton who provided statistical advice.

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Appendix 1. List of observers participating in the survey on the long-term relationship between *Chrysolina quadrigemina* Suffr. and St. John's wort, *Hypericum perforatum* L.

Observer	Location	Number of sites
A. State government Inspectors of Lands, Victoria (Department of Conservation, Forests and Lands)		
T.K. Barnard	Wodonga	4
L.J. Barton	Corryong	2
L. Broadhurst	Walwa	2
J. Carr	Alexandra	5
J. Corrie	Castlemaine	2
A.J. Dobson	Mansfield	4
T. Fitzpatrick	Swifts Creek	2
J.R. James	Tallangatta	2
A. Johnson	Broadford	2
P. Larkin	Beechworth	4
D.K. Muir	Benalla	3
B.S. Oswald	Stratford	4
J.W. Pollard	Warrandite	1
K.P. Rayner	Maryborough	3
E.C.W. Smith	Wangaratta	4
S.R. Williamson	Bright	3
		47
B. Local government Noxious Weeds Officers, NSW		
C. Austin & D. Baldwin	Upper Macquarie County	6
J. Cherry	Central Northern County	4
R. Connell	Tumbarumba Shire	4
S.W. Dickson	Wingecarribee	1
T. Eaglestone	Cabonne Shire	1
P. Ellison	Tumut Shire	3
J. Fahey	Crookwell Shire	4
W. Forbutt	Young Shire	1
J. Kerrison	Harden Shire	2
T. Reed	Orange City	1
W. Ryan	Midwestern County	6
A.R. Smith	Bega Valley Shire	1
M. Steinhäuser	Cooma-Monaro Shire	1
C. Webb	Wellington Shire	2
		37
C. Private Landholders		
I.R. Arnott	Coolah Creek, NSW	3
E. Coram	Euchareena, NSW	1
A. McMaster	Cassilis, NSW	3
R. Moxham	Trunkey Creek, NSW	2
J. Nader & G. Reilly	Merriwa, NSW	2
		11
D. Others		
D.T. Briese & K.R. Pullen	CSIRO Division of Entomology, ACT	10
W. Jeffs	Kosciusko National Park, NSW	3
		13
	Grand Total	108

Appendix 2. The questionnaires used in the survey of the long-term relationship between *Chrysolina quadrigemina* Suffr. and St. John's wort, *Hypericum perforatum* L.

I. SPRING SURVEY OF ST. JOHN'S WORT CONTROL AGENTS.

A. DETAILS OF THE ST. JOHN'S WORT STAND.

1. Location (give name, plus distance to nearest major town)

.....

2. Approximate area of infestation (specify hectares or acres)

.....

For the following questions please indicate by a cross which best describes the weed infestation

3. Is the St. John's wort stand in an area that is:

mainly open	<input type="checkbox"/>
lightly timbered	<input type="checkbox"/>
densely timbered	<input type="checkbox"/>

4. This year does the St. John's wort stand consist of:

mainly scattered individual plants	<input type="checkbox"/>
a light infestation (scattered patches with isolated plants interspersed)	<input type="checkbox"/>
a dense infestation (large continuous cover or many dense patches)	<input type="checkbox"/>

5. Since last year's survey, has the infestation:

decreased greatly	<input type="checkbox"/>
decreased slightly	<input type="checkbox"/>
remained about the same	<input type="checkbox"/>
increased slightly	<input type="checkbox"/>
increased greatly	<input type="checkbox"/>

6. a) Is the area containing St. John's wort at present:

ungrazed	<input type="checkbox"/>
lightly grazed	<input type="checkbox"/>
heavily grazed	<input type="checkbox"/>

b) What animals are grazing?

7. Is the density of other ground vegetation at the site:

low	<input type="checkbox"/>
moderate	<input type="checkbox"/>
high	<input type="checkbox"/>

8. Are any of the following methods being used this year to control St. John's wort in this particular stand:

chemical herbicide	<input type="checkbox"/>
pasture improvement	<input type="checkbox"/>
mechanical removal	<input type="checkbox"/>
other (please state below)	<input type="checkbox"/>

.....

9. What is the average height of stems bearing seedheads?

0 - 10cm	<input type="checkbox"/>
10 - 20cm	<input type="checkbox"/>
20 - 30cm	<input type="checkbox"/>
30 - 40cm	<input type="checkbox"/>
40 - 50cm	<input type="checkbox"/>
50 - 60cm	<input type="checkbox"/>
60 - 70cm	<input type="checkbox"/>
70 - 80cm	<input type="checkbox"/>
80 - 90cm	<input type="checkbox"/>
90 -100cm	<input type="checkbox"/>

10. If large areas of St. John's wort had been defoliated by beetles over winter, what percentage of those plants have regenerated?

.....%

B. OBSERVATIONS ON *CHRYSOLINA* BEETLES.

11. What was the date this Spring when you first observed *Chrysolina* beetles feeding on St. John's wort?

12. Please indicate by a cross which description of the density of beetles and damage caused by them best fits the area being examined. (Examine at least 20 plants before answering this question.) If possible check the area again a few weeks after the initial

Appendix 2. Continued.

observation and indicate the highest rating.

- 0 No sign of beetles; no evidence of feeding damage to St. John's wort stands.
- 1 Beetles present, but only found after searching usually singly; no evidence of significant feeding damage to St. John's wort stands.
- 2 Beetles not very common, but obvious on first observation on the stand, occasionally in small groups of 2-5 per stem; little evidence of feeding damage, leaves chewed but no plants showing complete defoliation.
- 3 Beetles quite common, often up to 10-20 per stem on a few plants; feeding damage visible on some plants, with a few completely defoliated.
- 4 Large numbers of beetles, often over 20 per stem on some plants. Feeding fronts forming; complete defoliation of large sections of the St. John's wort stands, but some areas untouched.
- 5 Very large numbers of beetles, often 30-40 per stem on many plants in extensive feeding fronts; complete defoliation of virtually all the St. John's wort stand.

Date of first inspection

Date of follow-up inspection (if made):

13. REMARKS

If you have any other remarks to make, these can be placed below, e.g. if you can estimate losses in production due to the presence of St. John's wort, please do so.

If you have observed large populations of *Chrysolina* beetles in any other areas, please indicate the names of the locations below.

II. AUTUMN SURVEY OF ST. JOHN'S WORT CONTROL AGENTS.

A. DETAILS OF THE ST. JOHN'S WORT STAND.

1. Location (give name, plus distance to nearest major town)
2. Date of survey
3. Approximate area of infestation (specify hectares or acres)
4. a) Is the area containing St. John's wort at present:

ungrazed	<input type="checkbox"/>
lightly grazed	<input type="checkbox"/>
heavily grazed	<input type="checkbox"/>
- b) What animals are grazing?
5. Is the density of other ground vegetation at the site:

low	<input type="checkbox"/>
moderate	<input type="checkbox"/>
high	<input type="checkbox"/>
6. Since last autumn's survey, has the infestation:

decreased greatly	<input type="checkbox"/>
decreased slightly	<input type="checkbox"/>
remained about the same	<input type="checkbox"/>
increased slightly	<input type="checkbox"/>
increased greatly	<input type="checkbox"/>
7. What is the condition of the St. John's wort stems?

dead	<input type="checkbox"/>
poor condition	<input type="checkbox"/>
healthy	<input type="checkbox"/>
8. What is the average height of stems bearing seedheads?

0 - 10cm	<input type="checkbox"/>
10 - 20cm	<input type="checkbox"/>
20 - 30cm	<input type="checkbox"/>
30 - 40cm	<input type="checkbox"/>

Appendix 2. Continued.

- 40 - 50cm
 50 - 60cm
 60 - 70cm
 70 - 80cm
 80 - 90cm
 90 - 100cm

9. If large areas of St. John's wort had been defoliated by beetles last spring, what percentage of those plants have regenerated?
%

B. OBSERVATIONS ON CHRYSOLINA

10. *Chrysolina* beetles are normally not as obvious in autumn as in winter, so it is not possible to have a rating scale. In the space below, please record the number of beetles observed by you during a 5 minute search.

Chrysolina eggs are laid in autumn on the prostrate winter growth of St. John's wort. They are 1-2mm long, bright orange in colour and occur singly or in small groups of 2-4.

The larvae of *Chrysolina* are small pink, grey grubs which roll themselves into a ball when disturbed. They also occur in the winter growth of St. John's wort, upon which they feed.

Please check the winter growth of St. John's wort for 5 minutes, and indicate below whether any eggs or larvae were observed.

11. *Chrysolina* eggs present
 absent
 12. *Chrysolina* larvae present
 absent

REMARKS

If you have any other remarks to make, these can be placed below.

III. WINTER SURVEY OF ST. JOHN'S WORT CONTROL AGENTS.

A. DETAILS OF THE ST. JOHN'S WORT STAND.

1. Location
2. Date of Survey
3. What is the average length of the prostrate winter growth?
 0- 5cm 21-25cm
 6-10cm 26-30cm
 11-15cm 31+ cm
 16-20cm
4. Is the density of other ground vegetation at the site: low
 moderate
 high

B. OBSERVATIONS ON CHRYSOLINA

Chrysolina eggs are found on the prostrate winter growth of St. John's wort. They are 1-2mm long, bright orange in colour and occur singly or in small groups.

The larvae of *Chrysolina* are small pink, grey grubs which roll themselves into a ball when disturbed. They also occur on the winter growth of St. John's wort, upon which they feed.

Please check the winter growth of St. John's wort for 5 minutes, and indicate whether any eggs or larvae were observed.

5. *Chrysolina* eggs present
 absent

Appendix 2. Continued.

6. *Chrysolina* larvae present
absent

The larvae of *Chrysolina* feed on the winter growth, eventually leaving only the bare stems remaining. Examine the winter growth in the survey plot for damage by *Chrysolina* and indicate the rating below which best describes what you see.

7. 0 - No signs of feeding damage on winter growth
- 1 - Signs of feeding on leaves, but *no* plants completely eaten
- 2 - Feeding obvious, a few plants completely eaten
- 3 - Large patches of winter growth eaten (up to 50% of plants)
- 4 - Most winter growth eaten (more than 50%), but some plants remaining
- 5 - All winter growth completely eaten

REMARKS

If you have any other remarks to make, these can be placed below.
