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Control of grape berry moth larvae using parasitoids: should it be developed?

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Abstract: Besides mating disruption techniques and progress in monitoring techniques (e.g. the use of food traps against females), biological control may reveal itself very efficient at controlling grape moth populations. Parasitoids active to control grape moths are known for long in vineyards; few of them were already described in the middle of the 19th century in French vineyards and their efficiency was already recognized especially against the diapausing and the first spring generations of the moths. Rather numerous attempts to release egg parasitoids have been done in different European countries using different species of trichogrammas. The results obtained varied a lot and could not yet clearly promote the use of this technique in vineyards. We believe that a biological control based on larval parasitoids could efficiently be developed as a valuable alternative to chemical control. In the present paper, we focus on larval parasitoids among which ichneumonids and chalcidoids (Hymenoptera) dominate, and present results obtained in different French vineyards (Bordeaux vineyard, Perpignan and Montpellier area, Côtes du Rhône and Alsace). We discuss factors that may favour or reduce their efficiency as biocontrol agents.

Key words: Parasitoids, biological control, viticulture, biodiversity, fitness, grape cultivars, Ichneumonids, Tachinids, Trichogrammas.

Introduction

Biological control in vineyard is a promising but challenging perspective, and surprisingly the development of biological control in viticulture suffers from a lack of studies. The main efforts have been done studying and attempting egg parasitoids releases (namely *Trichogrammas*) (see Castaneda-Samoya *et al.*, 1993; Reda Abd el Monsef, 2004 and Hommay *et al.*, 2010). Beside such studies, several others attempted to qualify the biodiversity of natural enemies in different European vineyards (Thiéry, 2008). This started in the middle of the 19th century (Audouin, 1842; Jolicoeur, 1894) until more recent years (*e.g.* Coscolla, 1980; Marchesini & Dalla Monta, 1994; Colombera *et al.*, 2001; Thiéry *et al.*, 2001; Barnay et al., 2001). Also the biology, ecology or behaviour of several parasitoids occurring in vineyards have been studied both in laboratories and field during these last years focussing on *Trichogrammas* (Stengel *et al.*, 1977; Le Rallec & Wajnberg, 1990; Hommay *et al.*, 2002; Moreau et al., 2009) or larval parasitoids (Chuche *et al.*, 2006; Xuéreb & Thiéry, 2006).

Rather numerous attempts to release egg parasitoids have been done in different European countries using different species of *Trichogrammas* which harvested very different efficacies. Currently the release of parasitoids in vineyards is very marginal, and biological control programmes at large scale in vineyards would require research and development attempting to identify the suitable candidate species to be used like the environmental conditions favouring these species. This would also require fine basic research concerning the physiology, ethology and ecology of the selected candidates.

Although grape training and pesticide practices may strongly affect the natural enemies population dynamics, most of the field studies concluded that parasitism (either egg or larval) varies according to ecological factors, *e.g.* climatic mismatch, variable host density, lack of alternative hosts, also pointing out that variable quality of the host affect the parasitoid reproductive success. In this paper, we present several ecological parameters influencing the parasitism efficacy.

Parasitoids and predators of grape moths in vineyards

Natural enemies of pest in vineyards have received interest for many years. During the middle of the 19th century, several published monographies already listed eggs or larval parasitoids, the main focus being put on the two main moth pests in French vineyards at this period, the grape berry moth (*Eupoecilia ambiguella*) and the leaf rolling tortrix (*Sparganothis pilleriana*). In a recent review, Thiéry (2008) listed more than 70 species mainly represented in Hymenoptera which shows that vineyard is far from being a 'no parasitoid's land'. In fact parasitoids abundance and diversity may vary a lot throughout the season, between the different grape production areas but also as a consequence of large range of different ecological factors (host density, alternative hosts, grass or floral cover, hedges).

Neighbouring natural landscapes probably play an important role in natural enemies population level (Genini, 2000), even though we miss accurate data from vineyards to properly consider their effect. Interestingly, also natural enemies' biodiversity exists in most of the European vineyards. For example, several oophagous parasitoids as trichogrammas, or larval parasitoids as the tachinid *Phytomiptera nigrina* and various hymenopteras as *Campoplex capitator*, *Dibrachys* spp (*cavus*, *affinis*), *Dicaelotus inflexus, Diadegma fenestralis, Itoplectis maculator, Scambus elegans* or *Exochus* spp. (*tibialis*, *notatus),* occur and are regularly found in different European vineyards (Table 1).

Several factors affect the parasitism efficacy

Latitude, climate match or mismatch and vineyard location

These factors are probably not enough investigated. However, in a recent elegant study, Moreau *et al.* (2010) sampled *Lobesia botrana* larvae in different vineyards from Alsace, Switzerland and east South France and compared the larval parasitoids occurrences (Table 2). This shows that both diversity and major species vary according to both latitude and climate, though grape cultivars also contribute to these differences (see below).

This work matches previous studies which also suggest that parasitoids species distribution vary in France according to latitude and climate (Thiéry *et al.*, 2001). Several species are characteristic of Mediterranean viticulture, like for example *P. nigrina* or also *C. capitator* which is classically found in most of Mediterranean viticulture countries though this species has a broader distribution also occurring for example in Switzerland. Because vineyards present a great diversity of climatic conditions, climate match or mismatch is of primary importance and conditions the success of certain parasitoids. During these 2 successive years of study, the species *Exochus tibialis* was exclusively found in Switzerland and Alsace, and dominant in 2003 in the Valaisan vineyards (Table 2), while *P. nigrina* occurred exclusively in the south of France (Côtes du Rhône). In the study conducted by Moreau *et al.* (2010), almost 3 times fold less parasitoids were found in 2004, as compared to 2003, but the vineyards sampled were different.

Table 1. Non exhaustive list of parasitoids (alphabetic order) reported from literature as natural enemies of grape moths in vineyards in West European countries. This list is selected and implemented from a broader one (Thiéry, 2008). Only species reported by at least 2 references in the former list are presented here. EA = *Eupoecillia ambiguella*, LB = *Lobesia botrana*, SP = *Sparganothis pilleriana,* Beth = Hym. Bethylidae, Chal = Hym Chalcidoidea; Ichn = Hym. Ichneumonidae, Tach = Dip. Tachinidae. *Pteromalus* and *Trichogramma* spp regroup several species.

Species	Family	Host orders	Reported hosts in vineyardsI	Parasitized instars (when known).
Agrothereutes abbreviatus (F.)	**Ichn**	Lepidoptera	LB EA	pupae
Ascogaster quadridenata (Wesm.)	**Ichn**	Tortricidae	LB	larvae pupae
Brachymeria minuta (Wesm.)	**Chal**	Lep, Dip	EA	
*Campoplex capitator (*Aub.)	**Ichn**	Tortricidae	LB EA	L3-L4
Diadegma fenestrale (Holm.)	**Ichn**	Lepidoptera	LB SP	larvae
*Dibrachys affinis (*Masi)	**Chal**	Lepidoptera and other insects	LB-EA-SP	L4-L5
Dibrachys cavus (Walk.) *(*syn *boucheanus)*	**Chal**	Lepidoptera and other insects	LB-EA-SP	L4-L5 pupae
*Dicaelotus inflexus (*Thom.)	**Ichn**	Lepidoptera	LB	pupae
*Dicaelotus resplendens (*Holm.)	**Ichn**	Lepidoptera		
Elachertus affinis (Masi)	**Chal**	Tortricidae	EA-LB-SP	larveae
Exochus tibialis (Holm.)	**Ichn**	Lepidoptera	LB	larvae pupae
*Gelis areator (*Panz.)	**Ichn**	Lep, Hym	LB EA	larvae
Goniozus claripennis (Först.)	**Beth**	Lepidoptera	PS	larvae
Ischnus alternator (Grav.)	**Ichn**	Lepidoptera	LB	pupae
Itoplectis alternans (Grav.)	**Ichn**	Lep, Hym	LB, SP	pupae
Itoplectis maculator (Fabr.)	**Ichn**	Lep, Hym	LB EA SP	pupae
Itoplectis tunetana (Schmied.)	**Ichn**	Lep, Hyma	L EA	pupae
Phaeogenes melanogonos (Gmel.)	**Ichn**	Lepidoptera	EA SP	pupae
Phaeogenes planifrons (Wesm.)	**Ichn**	Lepidoptera	SP	pupae
Phytomyptera nigrina (Meig.) (= *nitidiventris*)	**Tach**	Lepidoptera	LB	larvae
Pimpla spuria (Grav.)	**Ichn**	Lepidoptera	LB	pupae
Pimpla turionellae (L.)	**Ichn**	Lepidoptera	LB EA SP	pupae

Species	Family	Host orders	Reported hosts in vineyardsI	Parasitized instars (when known).
Pteromalus spp *More than 8 species*	**Ichn**	Lep, Dip, Col, Hym	LB EA SP	larvae pupae
Scambus elegans (Woldst.)	**Ichn**	Lep, Hym	LB	larvae
Tranosemella praerogator (L.)	**Ichn**	Lepidoptera	LB EA SP	larvae
Trichogramma spp *More than 15 species*	**Chal**	Lepidoptera	EA LB SP	eggs
Triclistus sp .	**Chal**	Lepidoptera	LB	larvae pupae

Host density

Host density is a classical major factor affecting natural enemy populations. It becomes crucial for example in specialist parasitoids which lack alternative hosts to achieve their reproductive cycle (Lane *et al.*, 1999). The effect of host density on the parasitoids/predators population level and thus capacities to control the targeted pest is thus well documented in many biological antagonists. With most parasitoids searching for specific development stages, this host density should be viewed at the specific targeted development stage. Xuéreb & Thiéry (2006) showed for example a good correlation between the parasitism by natural populations of *C. capitator* and the number of *L. botrana* larvae per bunch (Figure 1).

Also the host searching behaviour of parasitoids is often affected by host density in the patch. For example, the egg discovery rate of *L. botrana* by *T. cacoeciae* varies as a function of host density (Hommay *et al.*, 1999).

Season of the year and variation between years

Except for the monovoltin leaf rolling tortrix, the grape moths (*L. botrana*, *E. ambiguella* and *Argyrotenia pulchellana*) accomplish at least two generations per year, and their population level may vary sometimes a lot from one generation to another. Therefore and because host density (see above) is of primary importance, parasitoids populations may suffer or profit from these variations.

Variation between successive years is also a trend that has been often observed in different vineyards. This can also be illustrated by the data provided by sampling in 2003 and 2004 *L. botrana* larvae from different vineyards in France and Switzerland (Moreau *et al.*, 2010) (Table 2), but also by data from Xuéreb & Thiéry (2006) (Table 3).

Variation of parasitoids/predators population density may also be due only to their intrinsic annual life cycle or to their life style. Such within year variation is known for long in *C. capitator*. It is worth noting that this species named one century ago *C. majalis* meaning *Campoplex* of may (Audouin, 1842; Jolicoeur, 1894) can diapause in diapausing berry moths chrysalids (*L. botrana* and *E. ambiguella*)(our unpublished data). This species has traditional higher efficiency during the first generation of the moth. These observations were confirmed by Xuéreb & Thiéry (2006) (Table 3). In the same study, *S. elegans* was only found during 2 successive years during summer and never parasitized the spring generation of *L. botrana*.

Intrinsic variation due to the parasitoid life cycle combined with variation of host population level within the year may also amplify such variations.

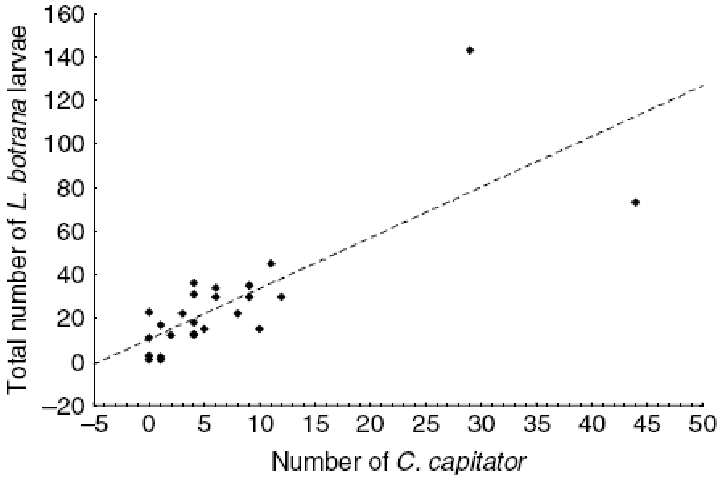

Figure 1: Host density relationship with the number of C*ampoplex capitator* parasitizing the *Lobesia botrana* larvae (from Xuéreb & Thiéry, 2006, see this reference for more details).

Table 2. Species diversity in larval parasitoids emerged from *Lobesia botrana* sampled in different French and Swiss vineyards. VS = Valais, VD = Vaud, F = France. Parasitoid species, Ichneumonidae: *Et* = *Exochus notatus, Aa* = *Agrypon anxium, Cc* = *Campoplex capitator, Im* = *Itoplectis maculator, Di* = *Dicaelotus inflexus, Df* = *Diadegma fenestrale,* Braconidae: *As* = *Apanteles* sp., Bethylidae: *Gc* = *Goniozus claripennis,* Tachinidae: *Pn* = *Phytomyptera nigrina, Triclistus meridiator* was found only once

Year	*Locality*	*Cultivar*	*Et*	*Aa*	*Cc*	*Im*	*Di*	*Pn*	*Gc*	*Df*	*As*
	Yvorne (VD)	Pinot noir	6	1	2						
	Yvorne (VD)	Chasselas	7		3						
	St P-de Clages (VS)	Pinot noir	18								
2003	St P-de Clages (VS)	Gamay	8	1							
	St P-de Clages (VS)	Chasselas	20	2	2						
	Tavel (F)	Grenache			6		1				
	Colmar (F)	Gewurtz	3			2	1				
	Colmar (F)	Riesling				1	3				
Total 2003			***62***	***4***	***13***	***3***	***5***	***0***	***0***	***0***	***0***
	Roquemaure (F)	Grenache						16			1
	Roquemaure (F)	Syrah		1	1				1	5	
2004	Sion (VS)	Pinot noir									
	Sion (VS)	Chasselas	2								
	Nyon (VD)	Chasselas									
	Nyon (VD)	Chardonnay	3								1
Total 2004			***5***	***1***	***1***	***0***	***0***	***16***	***1***	***5***	***2***

Effect of grape cultivars and larval food plant

Grape cultivar, but also host plant consumed as a larva by *L. botrana* which is a polyphagous species (Thiéry & Moreau, 2005; Maher & Thiéry, 2006) surprisingly influenced the succeptibility of its eggs to be parasitized by *Trichogramma evanescens* (Moreau *et al.*, 2009; and Figure 2). Interestingly this study also showed that the reproductive success of the

Trichogrammas emerging from the different eggs also varied like its larval growth speed. A similar result was found with eggs produced by moth fed as larvae on food supplemented with different host-plant of *L. botrana* and exposed to *Trichogramma cacoeciae* (Thiéry, Pizzol & Wanjberg, unpublished data).

Table 3. Parasitism rates by natural populations of *Campoplex capitator* against *Lobesia botrana* during the first 2 successive generations of the year. See Xuéreb & Thiéry, 2006 for details on the procedure.

Parasitoid/cultivar	2000		2001		Mean Pr per cultivar
	G1	G2	G1	G2	
All parasitoids					
Cabernet Franc	50.00	19.05	100.00	21.01	47.51
Cabernet Sauvignon	66.67	34.62	30.00	24.56	38.96
Merlot	20.00	30.67	25.00	31.16	26.71
Sauvignon	36.36	26.67	33.33	20.28	29.16
Sémillon	33.33	33.33	77.78	17.20	40.41
Mean Pr per collection	41.27	28.87	53.22	22.84	
Campoplex capitator					
Cabernet Franc	50.00	4.76	100.00	19.33	43.52
Cabernet Sauvignon	66.67	11.54	30.00	22.81	32.75
Merlot	20.00	26.67	25.00	30.15	25.48
Sauvignon	36.36	17.78	33.33	15.57	25.76
Sémillon	33.33	29.63	77.78	16.96	39.43
Mean PrC per collection	41.27	18.07	53.22	20.96	

G1, first generation; G2, second generation; Pr, parasitism rate; PrC, relative contribution of the most abundant larval parasitoid.

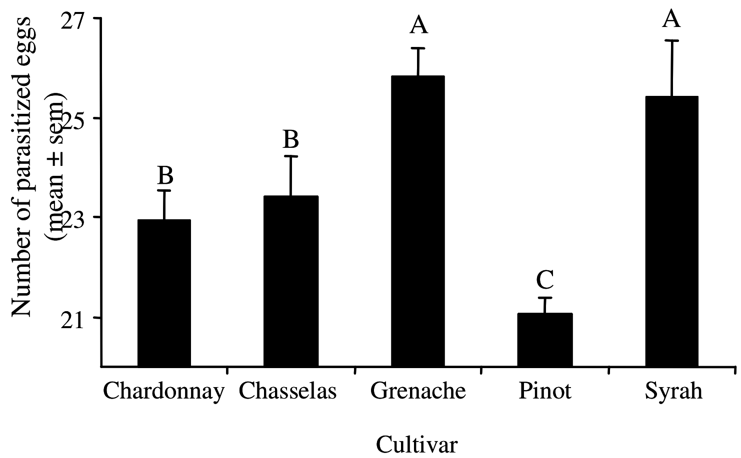

Figure 2: Effect of different grape cultivar consumed by *Lobesia botrana* as a larva on the parasitism rate of its eggs by *Trichogramma evanescens* (N° of parasitized eggs per female of *Trichogramma. evanescens,* see Moreau *et al.*, 2009 for experimental details).

These first studies strongly suggest that grape cultivar may also interfere with the host quality and thus their parasitism rate. However in the study done by Xuéreb & Thiéry (2006), the five cultivars tested did not significantly influence the larval parasitism by *C. capitator,* except Merlot and possibly Sauvignon on which *L. botrana* larvae were less parasitized by *C. capitator* in first spring generation (see Table 3).

Conclusion

A quick and simple answer to the question asked in the title should be yes. However successful use of natural enemies as a pest control techniques requires important efforts concerning the basic knowledge of the parasitoid or predator species and their relation with their targeting hosts. Also one key point in biological control is how to favour survival and high fecundity of the beneficial organisms. Research has thus a challenge to improve its knowledge of tritrophic interactions in vineyards which are to date not enough investigated. Viticulture has also to evolve towards practices that are more environmentfriendly, thus favouring the populations of natural enemies by offering them fairly favourable environmental conditions. Coupling releases of natural enemies naturally occurring in vineyards and vineyard/landscape management techniques in order to favour the installation and reproductive success of the beneficial organisms is an interesting way for future efficient biological control in vineyards.

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