Decision making on the control of the European grape berry moth *Lobesia botrana* in the "vinhos verdes" region, in the Northwest of Portugal

Modèle pour le control du vers de la grappe *Lobesia botrana* à la région the « vinhos verdes » dans le nord-ouest du Portugal

Toma de decisiones sobre el control de la polilla del racimo de la vid *Lobesia botrana* en la región de «vinhos verdes» al noroeste de Portugal

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Abstract

A conceptual model is proposed as a decision tool for control of European grape moth Lobesia botrana Denis & Schiffermüller (Lepidoptera; tortricidae) in the "vinhos verdes" region in the Northwest of Portugal. The aim is to use simple methods of estimating the pest population so the farmers can make future decisions earlier in the season and avoid the effects of a third generation. A dichotomous decision tree was used to structure the alternative choices by each farmer. For the three L. botrana generations, generation by generation, the most user friendly and adapted estimates were selected. The model can be formatted in an Excel algorithm and can be easily copied for use in the entire region. With further information on the susceptibility of different grape variety to L. botrana - this model should be adaptable for progressive elaboration and refinement. By using local observations and decision thresholds the model can be extended to other regions.
Keywords: Lobesia botrana, decision making, integrated pest management

Résumé

On propose un modèle conceptuel comme outil de décision pour le contrôle du vers de la grappe Lobesia botrana Denis et Schiffermüller (Lepidoptera; tortricidae) dans la région «de vinhos verdes» dans le nord-ouest du Portugal. Le but est d'employer des méthodes simples pour estimer la population du parasite pour permettre que les fermiers puissent prendre de futures décisions plus tôt dans la saison et éviter ainsi les effets néfastes d'une troisième génération. Un arbre dichotome de décision a été employé pour structurer les choix alternatifs. Pour les trois générations de L. botrana, génération par génération, des observations simples et adaptées à l'utilisateur ont été choisies. Le modèle peut être composé dans un algorithme d'excel et peut être facilement copié pour l'usage dans la région entière. Avec des informations additionnels tel que la susceptibilité de la variété à L. botrana ce modèle peut être amélioré. En employant des observations et des seuils locaux le modèle peut être adapté à d'autres régions.
Mots-clés: Lobesia botrana, décision, protection intégrée

Resumen

Se propone un modelo conceptual como herramienta de decisión para el control de la polilla del racimo de la vid europea Lobesia botrana Denis y Schiffermüller (Lepidoptera; tortricidae) en la región de «vinhos verdes» al noroeste de Portugal. El objetivo consiste en utilizar métodos simples para estimar la población afectada por una plaga y para que de esta forma los agricultores puedan tomar antes futuras decisiones en la temporada y evitar así los efectos nefastos de una tercera generación. Se ha empleado un árbol de decisión dicotómico para estructurar las alternativas. Para las tres generaciones de L. botrana, se han seleccionado, generación por generación, las estimaciones más simples y adaptadas al usuario. El modelo puede realizarse en algoritmo de Excel y se puede copiar fácilmente para su empleo en toda la región. Mediante información adicional sobre la susceptibilidad de diferentes variedades de vid a la L. botrana, este modelo debería poder mejorarse. Al utilizar observaciones y umbrales de decisión locales, el modelo puede extenderse a otras regiones.

Palabras claves: Lobesia botrana, toma de decisiones, control integrado de plagas

Introduction

In the “vinhos verdes” region a 70 thousand hectare demarcated region in the Northwest of Portugal (CVRVV, 2000) the European grape berry moth *Lobesia botrana* Denis & Schiffermüller (Lepidoptera; tortricidae) is responsible for direct losses due to the damage cause to the grapes and indirect losses by allowing access to the grey mould *Botrytis cinerea* Pers.. This fungus has a mutualistic relation with *L. botrana* (Mondy *et al.* 1998) and is responsible for the rejection of grapes for the quality “vinhos verdes” wines and, consequently, is regarded as very dangerous in this region. Growers usually spray against this moth pest two or more times during the season but the insecticides frequently killed beneficials. Fungicides are sprayed for downy and powdery mildews 8 or more times and 2 additional fungicides sprays for grey mould control. The population dynamics are similar throughout the region, but the intensity of infestation and the dominant phenological stage of the insect differ between vineyards. Thus the decision to spray must always be taken for each vineyard. For this reason the model has been developed to vineyard data. Since meteorological data are not always available for each vineyard, it is not possible to apply models integrating temperature records, which have been developed for insect management in general (Logan, 1988, Taylor, 1981, Harcourt & Yee 1982, Hudes & Schoemaker, 1988) and for *L. botrana* in particular (Lozia & Vita, 1987; Briere et al 1999; Briere & Pracos, 1998; Gabel & Mocko 1984). Other models, like those in Ashford *et al.* (1970) and Birley (1977) were used to analyse census data and represent life-tables, but are largely dependent on large biological data sets, and do not improve, necessarily, decision making in real time. Use of dichotomous decision tree enables a decision to be made by focussing on relevant information in a complex situation. The alternative choices are identified and enable users to evaluate the results achieved. The observed diversity in the microclimates within the region and the large differences in pest intensity among vineyards, even close together, require accurate data from each field.

2. The European grape moth in the “vinhos verdes” region

2.1. Vineyards studied

The current work started with a study of the population dynamics from the emergence of the first adults in spring until grape harvest. In the “vinhos verdes” region, *L. botrana* has three generations, with the second and third generations often superimposed. 16 vineyards were observed during 1998 and 1999, 14 of them common to both years (Table 1). These observations were weekly in some vineyards but in others, after one initial observation there was only one additional for each *L. botrana* generation. In all vineyards a close contact was kept with the technician or decision-maker involved with crop protection. A pheromone trap was installed in 14 vineyards in 1998 and 16 vineyards in 1999.

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Table 1. Study vineyards' characterisation

	Farm location	DM	1998 pheromone trap *	1998 visual observations **	1999 pheromone trap *	1999 visual observations **
V1	Arcos de Valdevez	T	2	2	2	2
V2	Arcos de Valdevez	T	2	2	2	2
V3	Arcos de Valdevez	T	2	2	2	2
V4	Barcelos	T	2	2	2	2
V5	Braga	T	1	-	1	-
V6	Póvoa de Lanhoso	G	2	1	2	1
V7	Cabeceiras de Basto	T	2	-	2	-
V8	Felgueiras	T	-	-	2	1
V9	Lousada	T	-	-	1	1
V10	Penafiel	T	2	2	2	1
V11	Penafiel	T	2	2	2	1
V12	Penafiel	T	2	-	2	1
V13	Penafiel	G	1	1	-	-
V14	Marco de Canavezes	G	1	1	2	1
V15	Amarante	T	-	-	2	-
V16	Baião	T	-	-	2	1
V17	Castelo de Paiva	G	2	1	-	-
V18	Castelo de Paiva	T	2	-	2	-

DM Decision-maker T= field technicien; G= grower/owner

* pheromone trap (- =vineyard not observed 1=moth count once per generation 2=moth count every week)

** visual observations (-= not observed 1=one control each generation, 2=one control each week)

The development stages of *L. botrana* (adults, eggs, larvae and pupae) and signs of their presence (nests, chorions, puparia and/or perforated berries) were used to determine the changes in the pest population thought the season. The data were tabulated in spreadsheets for each vineyard. Data for one vineyard (Fig.1) shows the activity of males as shown by pheromone trap catches. Eggs, which are 1 mm, are very difficult to observe especially as they are often on the less visible side of the grapes. However larvae detected by the number of nests in 1st generation and perforated berries for the 2nd and 3rd generations, which often overlap, increase significantly at the end of the season. Larvae of the 3rd generation feed on the berries that are beginning to ripe and are rich in sugars. A single larvae feeding on several berries can induce high losses, when conditions are also ideal for rapid development of *B. cinerea*. Within a few days fungi can be detected in all the vineyards when close to harvest but chemical treatments are not permitted due to their harvest-intervals.

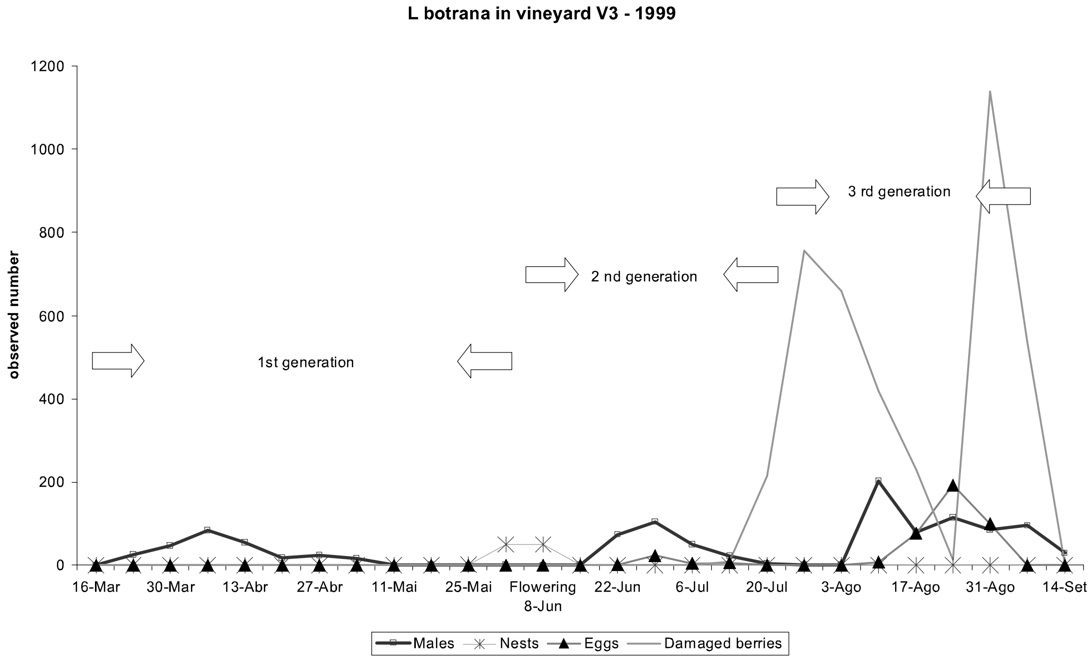

Figure 1. *L. botrana* developmental phases in vineyard V3, 1999.

2.2. Control strategies

Grape-growers not practising Integrated Pest Management (IPM), nor following the instructions of the Advisory Services, treat *L. botrana* in first generation, usually by adding an insecticide to a fungicide treatment for mildew. IOBC/WPRS guidelines for Integrated Production have been used to develop strategies, which are used in several vineyard regions in Europe. For the "vinhos verdes" region, the official strategy recommends three insecticide treatments based on the following thresholds: for the first generation 100 nests in 100 grapes, for the second and the third generation 1% damaged grapes due to *B. cinerea*. A grape is considered damaged one when either eggs and/or perforated berries are present (Gonçalves & Cavaco, 1997; DGPC, 2000). Apart from when growers have made a strategic decision to adopt mating disruption with pheromone, they can use only certain insecticides (Table 2) when adopting IPM protection.

Table 2. Insecticides allowed for IPM grapes in Portugal

pesticide type	pesticide	timing of application	harvest interval
biological	*Bacillus thuringiensis*	egg hatching	0 days
	Bacillus thuringiensis	egg hatching	0 days
insect growth regulation	fenoxycarb	eggs and new larva	2 weeks
	lufenuron	new larva	2 weeks
	tebufenozide	eggs and new larva	2 weeks
	flufenoxuron	new larva	8 weeks
classical OP.	phosalone	larva	4 weeks

3. Decision making model

3.1. The perception of the decision maker

Close contact with the decision-makers made it clear how difficult it is for them to achieve correct perceptions of pest situations: 8 of the 14 technicians/growers had poor results, 11 considered it difficult to carry out the observations for risk assessment and all of them mentioned the lack of useful information from advisory services. Mumford & Norton (1984) stated that perception is based on a decision-maker's own knowledge and experience: lack of confidence in their own observations was the main cause of bad decisions, and in consequence poor results.

3.2. Risk assessment model

Estimates

To determine which estimates could be used in a vineyard to satisfy a need for precision, easy use and enough time to act, field data was organized in Tables 3, 4 and 5 for each generation respectively. In this tables damage (expressed as percentage infestation) was related to possible estimaters such as nests, catches and perforated berries.

Table 3. First generation estimates

1 st generation		Damage	Estimates		
		infestation	**nests**	**catches**	
year	vineyard	*	number **	max ***	total****
1998	**V1**	0	0	2	3
	V2	0	0	1	1
	V3	0	0	13	44
	V4	1	1	134	71
	V10	0	0	6	16
	V11	0	0	18	73
1999	**V1**	5	5	19	46
	V2	30	42	52	100
	V3	46	50	83	282
	V4	12	16	22	216
	V8	15	20	ni	367
	V9	13	30	38	216

* % grapes damaged by 1st generation larvae

** at flowering, 1st week of June

*** maximum captures in a week

**** total for 12 weeks for 1st generation

The number of nests in 100 grapes gave the best indication of the first generation. Although the vines may compensate for a small amount of damage at this stages spraying against this generation has two objectives: to stop the damage from spreading to a level which could cause economic losses and to reduce the population that gives rise to the second generation. Poor correlation between the number of moth in the pheromone trap catches and the damage in the vineyards (Stockel, 1987; Roehrich & Boller, 1991; Bagnoli & Goggioli, 1993) has usually led to such data being perceived as useless (Gonçalves, 1991). Previous investigations carried out in various European regions had proposed pheromone catch rates thresholds for each generation (Stockel 1987, Haub 1992; Baillod *et al.* 1993) but in the model proposed in this paper, the trap captures record is used for the action decision during the 2^{nd} and 3^{rd} generations.

Table 4. Second generation estimates

2nd generation		Damage	Estimates					
			nests	**catches**	**catches**	**catches**	**perforeted**	
		infestation	**1st**	**1st**	**1st**	**2nd**	**berries ***	**eggs ****
year	vineyard	%	100 grapes	max	total	max	100 grapes	100 grapes
1998	**V1**	0	0	2	3	1	0	0
	V2	0	0	1	1	3	0	0
	V3	0	0	13	44	5	0	0
	V4	10	1	134	71	29	60	2
	V10	0	0	6	16	6	0	0
	V11	0	0	18	73	2	0	0
1999	**V1**	55	5	19	46	16	295	2
	V2	83	42	52	100	86	408	25
	V3	83	50	83	282	104	757	24
	V4	15	16	22	216	51	210	2
	V8	0 §	20	ni	390	110	0 §	10
	V9	86	30	38	216	292	710	4

§ as the vineyard was sprayed with an ovicide on the first week of July no infestation was detected

ni no information available

* perforated berries in 100 grapes (maximun observed)

** number of eggs registered at grape closure

Eggs recorded on 100 grapes provide, without doubt, the best estimate for the second generation. Recording the number of perforated berries is also useful, but is too late and does not allow a decision on the use of insecticides effective on eggs and/or on first larval instars. As growers' objectives are linked to reducing damage on the berries earlier estimates should be considered. The table 4 made clear that information provided by pheromone traps and nest records from the firsts generation can be useful in the following situations:

- The absence of nests and low or nill captures during the 2nd generation, there should be no attack (e.g. vineyards V1, V2, V3, V10 and V11 in 1998)

Where nests are present and many moths are caught in the 2nd generation and there will most certainly be an infestation (e.g. all vineyards in 1999)

Table 5. Third generation estimates

3rd generation		Damage	Estimates					
			infestation	**perforated**	**catches**	**perforated**		**catches**
		infestation	**2 nd**	**berries 2 g**	**2 nd**	**berries 3 rd**	**eggs**	**3 rd**
year	vineyard	%	%	100 grapes*	max	100 grapes**	100 grapes	max
1998	**V1**	0	0	1	1	0	0	5
	V2	10	0	3	3	22	0	20
	V3	8	0	5	5	46	0	19
	V4	20	10	29	29	216	1	278
	V10	0	0	0	6	2	0	50
	V11	0	0	0	2	5	0	225
1999	**V1**	40	55	19	16	190	45	222
	V2	80	83	52	86	240	44	50
	V3	100	83	83	104	1140	192	225
	V4	17	15	134	51	90	32	206
	V8	8	0	0	110	2	0	78
	V9	57	86	38	292	224	200	165

* at closure

** maximum value, usually when grape is ripened

Decision making for the thrird generation is very difficult. Given the ever present danger already mentioned in the "vinhos verdes" region of *B. cinerea* attacks, the threshold level must be 1% damaged grapes for the third generation; this means the observation of one egg or one perfurated berry for 100 grapes. Egg observation is a good estimates but it should be kept in mind that they are very difficult to be observed. In years of low-pressure pest attack, as was the case in 1998, the fact that no eggs were observed could not be used as the only estimate – as in vineyards V2 and V3. The counting of perforated berries would have been the best estimate for the attack of this generation. However, for pest control purposes this estimator would have been useless because was already too late for a chemical intervention.

4. Risk assessment improvement using selected estimates

On the basis of the selected estimates, observed values for six vineyards in 1998 and for six vineyards in 1999 are shown in Tables 6 and 7.

B= number of nests in 100 grapes at flowering (approximately first week June or at the end of the first generation's flight)

C= number of captured moths in the pheromone trap in one week trap at pea-size grapes (approximately last week June)

D= damaged grapes (%) – with eggs or perforated berries – observed at the grape closure (approximately 1 and 15 July)

E= number of captured moths in the pheromone trap in one week at beginning of ripening (approximately first week August)

D1= damaged grapes (%) observed at ripening (approximately 1 to 15 August)

Table 6. Data of performed observations in 1998

1998	Time	Vin. phenology	Observation		V1	V2	V3	V4	V10	V11
1st generation	June,1st week	flowering	nests	B =	0	0	0	1	0	0
2nd generation	June,4th week	berry pea-size	captures of 2nd g. (max)	C =	1	3	5	29	6	0
	July,1st week	closure	damage grapes (%)	D =	0	0	0	10	0	0
3rd generation	August,1st week	beginning ripening	captures of 3rd g. (max)	E =	5	20	19	278	5	18
	August,2nd week	ripening	damage grapes (%)	D1 =	0	10	8	20 T	0	0
			% damaged at harvest	R=	10	20	40	1	0	0

T spray with insecticide

Table 7. Data of performed observations in 1999

1999	Time	Vin. phenology	Observation		V1	V2	V3	V4	V8	V9
1st generation	June,1st week	Flowering	nests	B =	5	30	46	16	20	30
2nd generation	June,4th week	berry pea-size	captures of 2nd g. (max)	C =	16	86	104	74	110	292
	July,1st week	closure	damage grapes (%)	D =	55 t	83 t	83 t	15 T	10 T	4
3rd generation	August,1st week	beginning ripenig	captures of 3rd g. (max)	E =	50	225	202	68	78	165
	August,2nd week	ripening	damage grapes (%)	D1 =	40 T	80 T	100 T	17 T	0	57
			% damaged at harvest	R=	40	12	100	8	8	100

t insecticide spray with poor results

T insecticide spray with good results

1998 was a low-pressure year but the 10% damage level at harvest, considered the threshold for the region, was surpassed in vineyards V2 and V3. Chemical treatment correctly applied on V4 during the third generation prevented an economic loss. The choice for no treatment in V1, V10 and V11 was also correct. In contrast 1999 was a high-pressure year. For this reason sprays were carried out on all the vineyards except V9. Because V9 was not treated there was a high loss at harvest. In V4 and V8 the correct timing of spraying prevented the pest achieving undesirable levels. In vineyards V1, V2 and V3 application at the incorrect time for treatment to the second generation did not prevent further pest development to high levels of the pest in third generation, which made the result of a treatment for the 3rd generation doubtful.

4.1. Decision tree

With the knowledge generated from the two season's data, a model was structured through the use of a dichotomous decision tree (Fig. 2). The first step was to identify the tactic alternatives and evaluate the associated consequences. The decision tree applied to the case study included the following components:

- list of possible alternatives (each condition has two answers: yes or no)
- possible consequences associated with each alternative (spray with an insecticide or don't spray; in all the situations without enough confidence, a field observation was proposed).

This made possible a decision to spray or not for each pest generation. This model was applied based on data (estimates) which were easily obtainable – such as the pheromone trap captures and nest records, whenever possible. If not, data on eggs and the perforated berries were also added to the model.

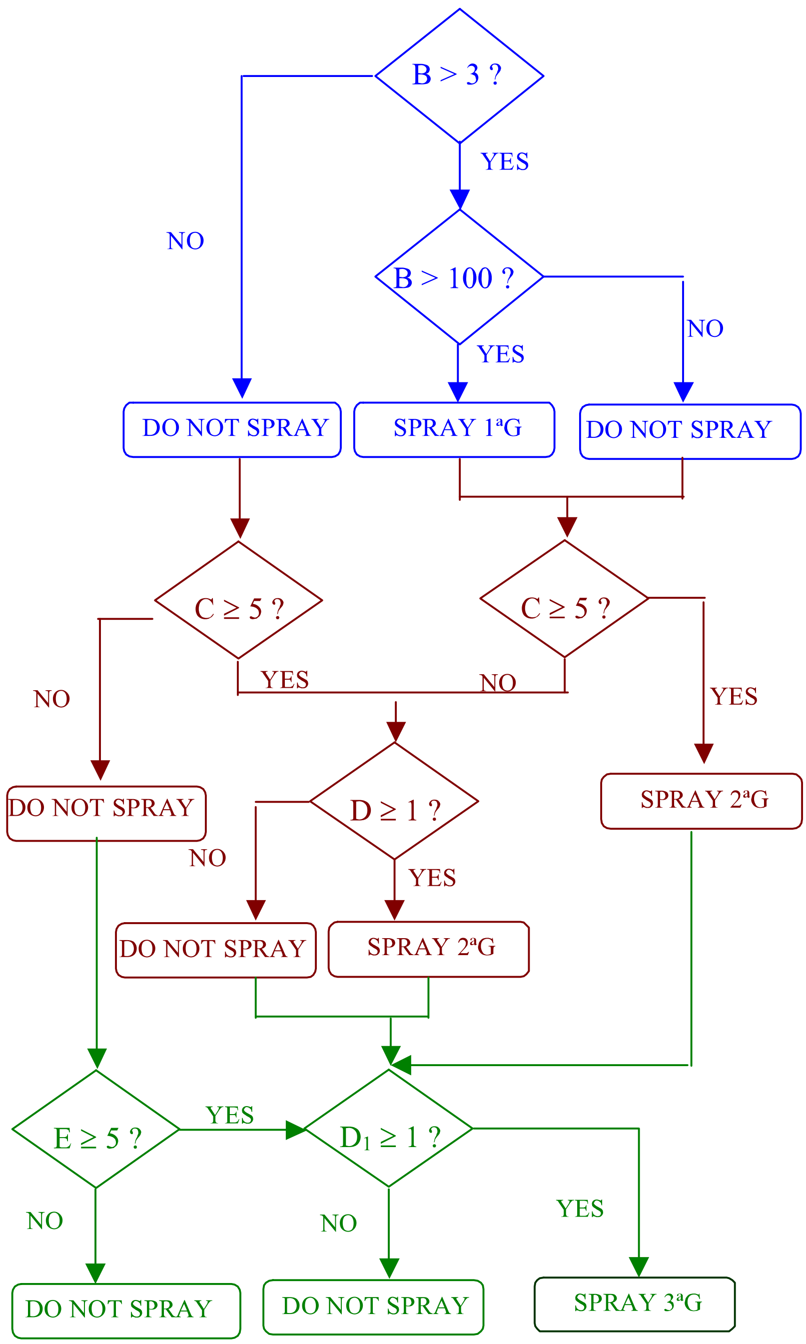

Fig 2. Decision tree flow-chart

For the 1st generation spraying with an insecticide must be performed if the number of nests (B) is bigger than 100 (the official threshold for this generation). For the 2nd generation the decision-makers can use data easily obtainable (number of nests and trap captures), those levels being 3 nests and 5 captured moths. When such information is insufficient they must use other estimate, the number of damaged grapes (D). In such case the official threshold is 1% damaged grapes. For the 3rd generation if no previous attacks were observed and no further trap captures were recorded, there is no need, in this situation, to do field observations to support a decision.

4.2. Validation of the conceptual model

During 2000, while field observations were carried out, data was inserted in Excel-spreadsheet and the conceptual model was tested. The model was run with data from the vineyards monitored during 2000 and the results obtained at third generation were consistent with the objectives (damaged at harvest less than 10%) (Table 8).

Table 8. Data of performed observations and decision making in 2000

2000		Vin. phenology	Observation		V2		V3		V5		V6		V8		V16
1 st generation	June,1st week	flowering	nests	B =	40		50		38		60		22		45
2nd generation	June, 4th week	berry pea-size	captures of 2nd g.(max)	C =	53		1		22		54		17		4
	July, 1st week	closure	damaged grapes (%)	D =	15	T	18	TT	3	T	10	T		TT	0
3rd generation	August, 1st week	beginning ripening	captures of 3rd g.(max)	E =	0		0		19		15		19		19
	August, 2nd week	ripening	damaged grapes (%)	D1 =	1	T	0		1	T	0		0		1
			% damage at harvest	R=	0		3		3		2		0		2

T insecticide spray

TT insecticide spray with repetition

t1 spray for another pest but active against EGM

Conclusions

The estimates of number of nests per 100 grapes provide a good decision on whether to control the first generation. In this generation the use of pheromone trap captures is not used because it would not make any useful contribution. As climatic conditions are expect to favour rapid *L. botrana* development and the possibility of *Botrytis cinerea* spread, 2nd and 3rd generation attacks are the most feared. So the control of the 2nd generation is essential to guarantee the quality at harvest. However, risk assessment for this generation, using official thresholds, is not easy. For these reasons the proposed conceptual model is based on assessments that are easy to obtain such as nests and pheromone trap records and if necessary on damaged grapes. With this proposed model field technicians or growers can decide if *L. botrana* treatments are needed with more confidence. The model can be easily used in an Excel spreadsheet. For the first time in the region the data obtained from pheromone traps could be used as a tool in the decision making process for grape-berry moth control.

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