Spatial Analysis of *Lobesia botrana* (Lepidoptera: Tortricidae) Male Population in a Mediterranean Agricultural Landscape in Central Italy

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ABSTRACT   The results obtained from the spatial analysis of pheromone-baited trap catch data of *Lobesia botrana* (Denis and Schiffermüller) males are reported. The research was undertaken in the Abruzzo region of central Italy. In the study area, vineyards (of *Vitis vinifera* L.) are the predominant cultivation, surrounded by hedgerows and small woodlots, and interspersed with cereal crops and olive groves. The main purpose of the study was to investigate the spatio-temporal dynamics of *L. botrana*, inside and outside vineyards, and to evaluate the effect of the landscape elements on pest distribution. A trend orientation over the experimental area was observed along the direction from northwest to southeast. Correlograms fitted using a spherical model showed in all cases an aggregated distribution and an estimated range having a mean of 174 m in 2005 and 116 m in 2006. Contour maps highlighted that spatial distribution of *L. botrana* was not limited to vineyards, but its presence is high particularly inside olive groves. The adult distribution on the experimental area changed during the season: hot spots of flight I were positioned inside olive groves; during flights II and III, they were concentrated in vineyards. *L. botrana* males were also captured in uncultivated fields, but never in high densities. Our results showed that a large proportion of the adult population of *L. botrana* inhabits areas outside those usually targeted by pest management programs. Thus, in Mediterranean agro-ecosystems, it is highly recommended to consider the whole landscape, with particular attention to olive crops.

KEY WORDS   geostatistics, vineyard, olive grove, *Lobesia botrana*

More and more attention has been paid to the importance of the mosaic of farmland habitats in integrated pest management (IPM) projects (Koul and Cuperus 2007). The influences of adjacent habitats to the entomocenosis of cultivated crops are well known and concern the presence of shelter for entomophagous in hedgerows, woodlots, and plants surroundings crops; the movement of arthropods on the crop–wild vegetation interface and along biological corridors; and the presence of alternative host plants as outer sources of pest infestations (Barrett 2000, Jeanneret 2000, Altieri and Nicholl 2004). New approaches of IPM tend to consider insect–landscape interactions in the context of the whole agro-ecosystem, including the role that different parts of the system play on the dynamics of pests (Ekbom 2000, Koul and Cuperus 2007). Such knowledge is necessary when we intend to introduce ecologically based management and precision farming approaches to our control strategies.

Three tortricids are known as grape pests in Europe, North Africa, and West Asia. Two of them, the grape berry moths, *Eupoecilia ambiguella* (Hübner) and *Lobesia botrana* (Denis and Schiffermüller), attack flower clusters and grapes of the grapevines; the third species, *Sparganothis pilleriana* (Denis and Schiffermüller), attacks mainly the shoots (Bovey 1966, Voigt 1972). *Eupoecilia ambiguella* and *L. botrana* occur in all Palaearctic vine-growing areas, but the former is the predominant species in the north, whereas the latter dominates in southern areas. Their abundance in the various viticultural areas is not uniform but can change within relatively short distances; in areas where both species occur together, *L. botrana* populations have higher densities at sunny exposures and during hotter seasons.

Lobesia botrana is described as polyphagous, and numerous host plants have been reported (Bovey 1966). Among them, Trematerra (2003) cited for Italy *Actinidia chinensis*, *Amorpha* spp., *Arbustus* spp., *Berberis* spp., *Clematis* spp., *Cornus* spp., *Crataegus* spp., *Daphne gnidium*, *Hedera* spp., *Ligustrum* spp., *Liriodendron* spp., *Lonicera* spp., *Myrtus* spp., *Olea europea*, *Rhamnus* spp., *Ribes* spp., *Rosmarinus* spp., *Serratula tintoria*, *Tanacetum vulgare*, *Viburnum* spp., *Vitis* spp., and *Ziziphus* spp.

Lobesia botrana overwinter as diapausing pupae. Diapause is controlled by photoperiodism induced in eggs and young larvae and the determining factor was the duration of scotophase (>11 h) (Desëo et al. 1981, Roditakis and Karandinos 2001). The mature larvae develop into pupae as soon as they have woven their cocoons. Under natural conditions, diapause is terminated in early February, and pupae enter postdiapause

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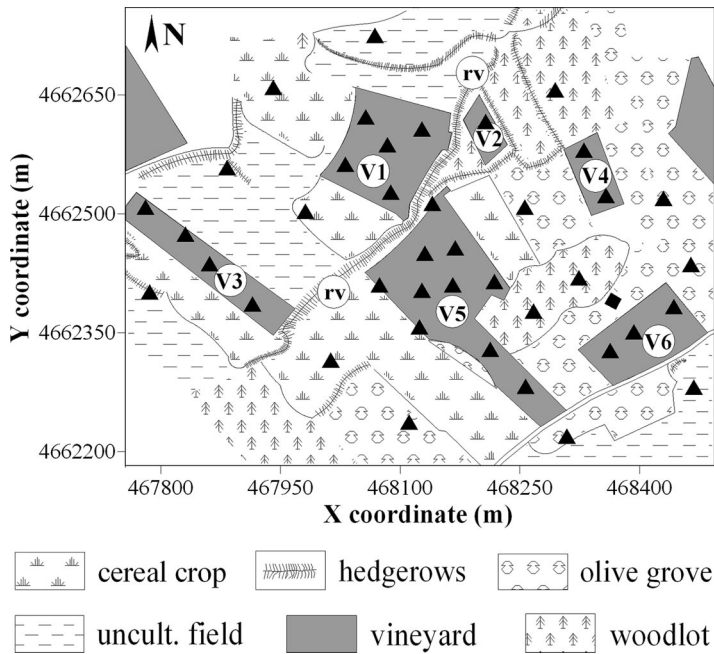
Fig. 1. Experimental area, with indication of vineyard position and landscape elements. V_1–V_6, sampled vineyards; rv, ravine location; triangles, trap location.

development, where temperatures <8°C are lethal (Roehrich 1969).

The number of *L. botrana* generation per year varies from one to four, depending on climate conditions (Roehrich and Boller 1991). In central and southern Italy, three generations occur during the growing season. Exceptionally, in hot years, there is a partial fourth generation, but the larvae often die before they are fully developed (Desëo et al. 1981, Pavan et al. 2006). Larvae of the first generation feed on inflorescences, those of the following generations damage ripening or mature berries, exacerbating infections of the gray mold fungus *Botrytis cinerea* Pers (Dalla Montà et al. 2007).

Little information is available about the spatial distribution of *L. botrana.* Aggregated distribution of larvae was observed by Badehnausser et al. (1999), using a Monte-Carlo test, and by Ifoulis and Savopoulou-Soultani (2006), using variogram analysis. Studies on adult distribution are very scarce and directed to evaluate the behavior of *L. botrana* in mating disruption applications (Feldhege et al. 1993, Charmillot et al. 1996). Peláez et al. (2006) used geostatistical maps to determine the spatial distribution of *L. botrana* inside vineyards.

In this paper, we provide a spatial analysis of pheromone-baited trap catch data of *L. botrana* males. The research was undertaken from 2005 to 2006 in the Abruzzo region of central Italy. In this area, commercial vineyards are the predominant cultivation, surrounded by hedgerows and small woodlots, and alternated with cereal crops and olive groves. The main purpose of the study was to investigate the spatio-temporal dynamics of *L. botrana*, inside and outside vineyards, and to evaluate the effect of the landscape elements on its distribution.

Materials and Methods

Study Area. The experimental area, ≈50 ha, was located in a hilly landscape of the Abruzzo region in central Italy, 100–200 m above sea. The landscape is characterized by the presence of alternating plots of cereals crops, olive groves, uncultivated fields, vineyards (of *Vitis vinifera* L.), and woodlots; it is crossed by a ravine with hedgerows, which divides the area into northwestern and southeastern hillsides (Fig. 1).

On the northwestern side, there were vineyards V_1 (≈1.5 ha in size), V_2 (≈0.3 ha), and V_3 (≈1 ha), with the Montepulciano d'Abruzzo cultivar. The various plots were surrounded by cereal crops and uncultivated areas. On the southeastern side, there were three more vineyards: V_4 (≈0.4 ha, with the Sangiovese and Trebbiano cultivars), V_5 (≈2.5 ha, with the Montepulciano d'Abruzzo cultivar), and V_6 (≈1 ha, with the Montepulciano d'Abruzzo cultivar). All plots were trained to the pergola system, a horizontal training system, except V_2 (simple curtain) and V_6 (spurred cord). Vineyards were separated by olive and cereal crops. Some oaks and walnut woodlots were located between vineyards V_2 and V_4 and between vineyards V_5 and V_6.

Lobesia botrana infestations were managed through the use of Chlorpyriphos or Fenitrothion in both years, with two treatments in August targeting third-generation larvae.

Data Collection. The activity of *L. botrana* adult males was monitored weekly using pheromone-baited
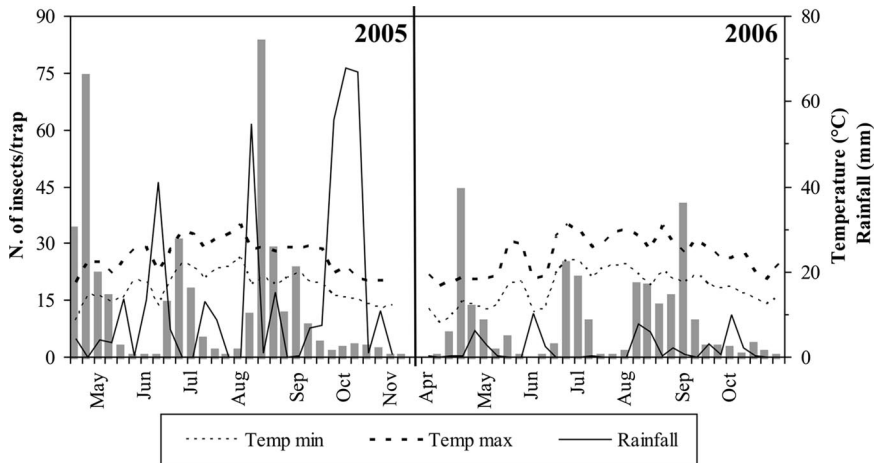
Fig. 2. Weekly catches of *L. botrana* in 2005 and 2006. Average weekly data for temperature minimums (Temp min), temperature maximums (Temp max), and rainfall were obtained from daily recordings of a meteorological station located in the experimental area.

sticky traps of the delta type, baited with 1 mg of synthetic pheromone blend containing (*E,Z*)-7,9-do-decadienyl acetate (Novapher, San Donato Milanese, Italy). The traps were placed in the grapevine canopy ≈1.8 m above ground. Pheromone dispensers were replaced every 4 wk, and sticky boards of the traps were replaced every 2–4 wk. Trapped adults were removed and counted weekly. The activity of males was monitored in 2005 and 2006 with 40 pheromone traps (Fig. 1).

During the first year (2005), field surveys were conducted from the beginning of April until the beginning of November. The sampling points were positioned as follows: 25 pheromone traps in vineyards; 6 traps in olive groves; 3 traps in cereal crops; 3 traps in uncultivated areas; and 3 traps in woodlots. In particular, in vineyards, the following number of traps were positioned: 5 traps in V_1, 1 trap in V_2, 4 traps in V_3, 2 traps in V_4, 10 traps in V_5, and 3 traps in V_6. During the second year (2006), field surveys were conducted from the end of March until the end of October. The sampling points were positioned as the previous year, with limited shift. In both years, distances between any two traps varied from a minimum of 51 m to a maximum of 687 m.

Spatial Analysis. Geostatistical methods were used to characterize the spatial distribution of *L. botrana* adult males. Insect count data were first squared-root transformed to approximate a normal distribution. Spatial dependence among observations was examined using the omnidirectional correlogram, with five lag intervals of 72 m up to a maximum distance of 360 m. Each lag interval, from the minimum to the maximum lag distance, contained 31, 102, 146, 144, and 145 pairs of sampling points, respectively. The spatial analysis was performed using Variowin version 2.2 (Pannatier 1996) for single weekly counts, provided that mean catch per trap was >1. Rossi et al. (1992) recommended the use of the correlogram or covariance function rather than semivariograms because the

first two functions consider localized means and variances, which tend to be nonstationary in insect populations.

When the presence of a large scale spatial trend was detected in correlograms, trend was removed by using the residuals obtained from a second-order polynomial regression expressed in the following way:

$$T(z) = b_0 + b_1x + b_2y + b_3x^2 + b_4y^2 + b_5xy \quad (1)$$

where $T(z)$ is the trend predicted from the squared-root count of males, x,y are spatial coordinates, and b_i are regression coefficients. The analysis was performed using SPSS software Version 13 (SPSS, Chicago, IL), after variables were centered to eliminate multicollinearity (DeCoster 2004).

Correlograms were fitted according to the spherical model. This model was preferred because, in the majority of cases (40%), it gave the best indicative goodness-of-fit (IGF), which is a standardized measure of fit provided by the software (Pannatier 1996). Also, using the same model allowed for a comparison among sampling intervals. The spherical model is defined by the nugget (C_0), the range (a), and the sill (C). The ratio $C_0/(C_0 + C)$, known as the k parameter, was used to evaluate the amount of randomness that exists in the

Table 1. Number of males, with relative percentage, collected by traps located inside or outside vineyards

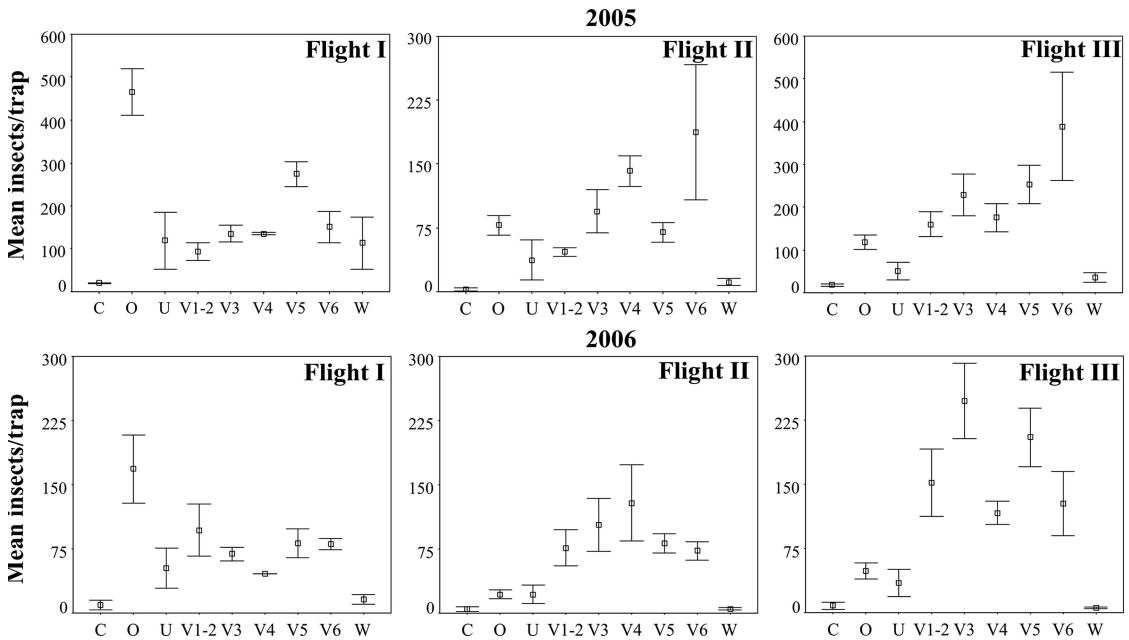| Flight	Number of individuals		Percentage	
	Inside vineyard	Outside vineyard	Inside vineyard	Outside vineyard
2005				
I	4,571	3,550	56.3	43.7
II	2,200	621	78.0	22.0
III	5,929	1,019	85.3	14.7
2006				
I	2,005	1,246	61.7	38.3
II	2,161	226	90.5	9.5
III	4,567	437	91.3	8.7

Fig. 3. Average number of *L. botrana* males (±SE) per trap during each flight of 2005 and 2006, collected on the main landscape elements where traps were positioned: cereals crops (C), olive groves (O), uncultivated fields (U), vineyards V_1–V_6 and woodlots (W).

data at distances smaller than the smallest distance between sampling locations. Values <0.8 indicate that the data are spatially autocorrelated and that the distribution of the population is aggregated (Journel and Huijbregts 1978).

For individual flights from the three generations, models obtained from semivariogram analyses were used to interpolate row counts with the kriging algorithm. We used lag intervals of 72 m up to a maximum distance of 360 m. Because the final objective in this case was an interpolated map, Chiles and Delphiner (1999) showed that variogram estimation is generally preferred over correlogram estimation.

The interpolated map of trap counts was conducted using Surfer software Version 8.05 (Golden Software, Golden, CO), and latitude and longitude were expressed as universal transversal mercator coordinates.

For flight I of 2005, data were detrended before analysis using the polynomial detrend option of the software. The interpolation grid from kriging was graphically represented as a contour map, with isoline representing expected moth counts. A base map showing the experimental area, with the same coordinate system, was placed on top of the contour map. Isolated zones of the contour map with higher catches are referred in the text as "hot spots."

Results

During 2005 and 2006, captures of *L. botrana* males displayed three peak flights (Fig. 2). In both years, the first peak was reached at the end of April and the second one at the end of June; the third peak was in the middle of August in 2005 and at the beginning of

Table 2. Parameters obtained from polynomial regression analysis of transformed *L. botrana* pheromone trap catches

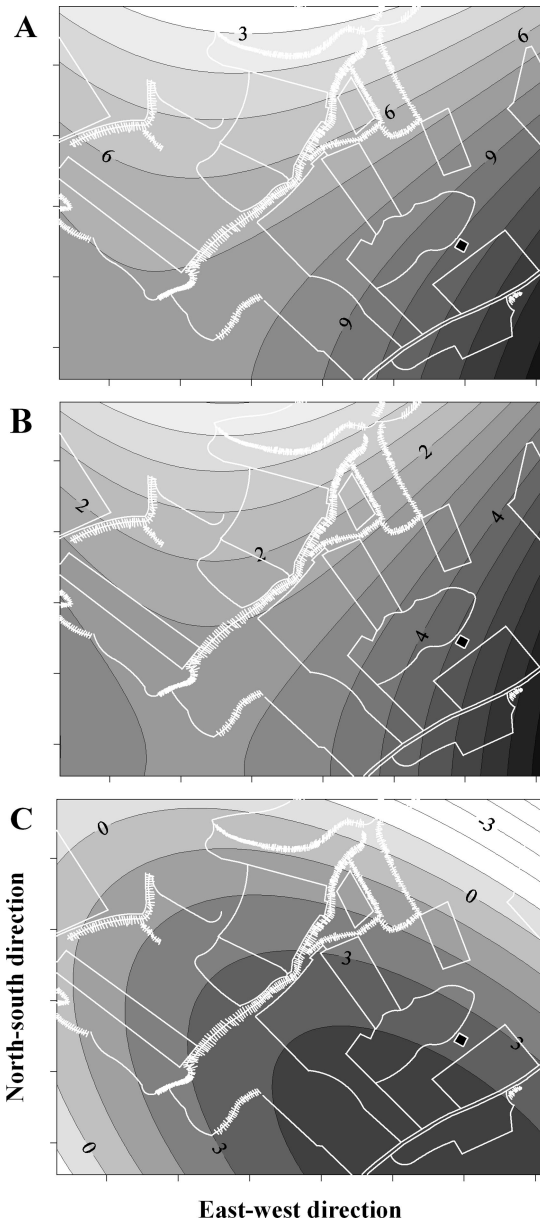| Sampling date	R^2	Parameters						F test	Significance level
		b_0	b_1	b_2	b_3 ($\times 10^{-5}$)	b_4 ($\times 10^{-5}$)	b_5 ($\times 10^{-5}$)		
2005									
I flight	0.38	14.19	0.008	−0.019	0.30	−8.00	−10.00	4.16	0.0050
18 April	0.46	7.47	0.002	−0.016	−0.89	−6.60	−0.68	5.89	0.0010
25 April	0.40	6.20	0.006	−0.006	−0.54	−6.19	−1.42	4.59	0.0030
2 May	0.38	7.17	0.008	−0.012	2.00	−1.80	−1.60	4.23	0.0040
20 June	0.41	2.74	0.005	−0.005	1.58	−1.12	−0.29	4.64	0.0020
29 Aug.	0.51	3.71	0.0002	−0.009	−2.20	−2.76	−2.90	7.08	0.0001
10 Oct.	0.52	0.53	0.0003	0.004	1.84	0.89	0.25	7.50	0.0001
17 Oct.	0.48	0.49	−0.001	−0.004	1.79	0.99	1.15	6.25	0.0003
24 Oct.	0.32	0.65	−0.002	−0.003	1.11	0.49	1.04	4.64	0.0020
2006									
10 July	0.38	3.89	0.0001	0.002	−1.6	−3.9	1.03	4.10	0.005
4 Sept.	0.38	7.46	−0.007	−0.006	−2.6	−7.8	−3.2	4.10	0.005

Fig. 4. Exemplary maps of trends obtained from polynomial regression analysis of 2 May (A), 20 June (B), and 20 August (C) *L. botrana* trap catches in the year 2005. White represents the experimental area.

Table 3. Parameters obtained by fitting the correlograms of the transformed trap catches of adult male *L. botrana* with the spherical model during 2005

Sampling date	Individuals N	Nugget (C_0)	Range (a)	Sill (C)	IGF $(\times 10^{-2})$	k
11 April	259	0.21	208	0.89	0.245	0.18
18	1858	0.07	251	1	2.51	0.06
25	1353	0.25	223	0.78	0.448	0.24
2 May	2966	0.28	176	0.66	0.553	0.30
9	886	0.19	115	0.83	0.157	0.19
16	651	0.32	192	0.79	0.384	0.29
23	106	0.08	144	0.94	0.634	0.08
20 June	576	0.43	165	0.50	0.217	0.46
27	1237	0.14	108	0.87	0.216	0.14
4 July	715	0.29	155	0.77	0.398	0.27
11	193	0.35	112	0.71	0.961	0.33
18	69	0.41	109	0.56	0.681	0.42
1 Aug.	65	0.53	54	0.50	0.054	0.51
8	447	0.44	148	0.65	2.12	0.40
16	3336	0.40	97	0.67	1.38	0.37
22	1152	0.36	104	0.66	2.33	0.35
29	458	0.28	303	0.84	1.80	0.25
5 Sept.	937	0.47	212	0.60	1.32	0.44
12	339	0.49	208	0.57	0.514	0.46
19	159	0.62	147	0.41	1.19	0.60
26	60	0.76	83	0.26	0.034	0.75
3 Oct.	104	0.53	205	0.52	1.70	0.50
10	123	0.51	273	0.55	1.40	0.48
17	114	0.50	327	0.62	0.334	0.45
24	90	0.29	223	0.77	0.01	0.27

ments. In flights II and III, the catch in olive groves declined, whereas they significantly increased within vineyards. Traps in uncultivated fields collected adults in vineyards during flight I, but later in the season, they decreased. Traps in cereal crops and woodlots had fewer captures than other traps except during flight I in 2005.

Regression analysis showed the presence of a trend in 9 of the 28 sampling intervals analyzed in 2005 and in 2 of 25 sampling intervals from 2006, with R^2 values ranging from 0.38 to 0.52 (Table 2). When mapping the trend over the experimental area, we observed a similarity between samples and a trend orientation along the direction from northwest to southeast (Fig. 4). The results reflect the distribution of the landscape elements in the experimental area, where olive groves are concentrated in the southeastern side and uncultivated areas are located in the northwestern side. However, the trend was observed only when captures of males were unbalanced between the two hillside, such as during flight I in 2005.

Among the 47 correlograms calculated for the weekly trap catches (Tables 3 and 4), the *k* parameter showed in all cases an aggregated distribution, with a lower mean in 2005 (0.35 ± 0.03) than in 2006 (0.53 ± 0.03). The estimated range of spatial dependence varied from 54 to 327 m, with a mean of 174 ± 14 m in 2005, and from 61 to 280 m, with a mean of 116 ± 11 m in 2006. Semivariograms calculated for generational flights, in both years, fitted a spherical model with zero nugget in all cases, and *a* ranging from 57 to 206 m (Fig. 5).

During flight I of both years, *L. botrana* males were distributed mainly on the southeastern sector of the

September in 2006. Later in the season, low level of catches continued into November in 2005 and the end of October in 2006.

The number of males captured outside the vineyards was highest during flight I and sharply decreased during flights II and III (Table 1). The influence of landscape elements on trap catch is shown in Fig. 3. During flight I in both years, traps positioned inside olive groves collected the highest number of males compared with traps located in other landscape ele-

Table 4. Parameters obtained by fitting the correlograms of the transformed trap catches of adult male *L. botrana* with the spherical model during 2006

| Sampling date	Individuals N.	Nugget (C_0)	Range (a)	Sill (C)	IGF $(\times 10^{-2})$	k
17 April	247	0.70	72	0.34	1.44	0.67
24	1758	0.70	72	0.33	1.05	0.68
1 May	539	0.78	111	0.25	0.176	0.76
8	385	0.65	104	0.39	0.448	0.63
15	77	0.31	140	0.75	0.318	0.30
22	211	0.38	140	0.66	0.785	0.37
19 June	122	0.46	83	0.60	2.95	0.43
26	1000	0.56	94	0.52	3.25	0.52
3 July	839	0.64	97	0.44	1.82	0.59
10	383	0.48	280	0.71	0.835	0.40
31	53	0.61	61	0.43	1.53	0.59
7 Aug.	776	0.41	111	0.67	0.858	0.38
14	757	0.47	111	0.59	1.18	0.44
21	551	0.49	101	0.54	0.751	0.48
28	648	0.51	126	0.56	0.398	0.48
4 Sept.	1614	0.50	176	0.56	0.514	0.47
11	385	0.50	76	0.57	0.857	0.47
18	112	0.65	76	0.41	1.15	0.61
25	108	0.72	119	0.30	0.64	0.71
2 Oct.	102	0.61	76	0.44	1.75	0.58
16	136	0.57	205	0.48	0.536	0.54
23	59	0.64	115	0.36	0.467	0.64

study area, and hot spots were located in olive groves (Figs. 6 and 7). Occurrence in vineyards was also consistent, especially in V_5, where a hot spot was on the border of the field, near olive plants, and inside V_1 in 2006. *L. botrana* males were also trapped in uncultivated areas of northwestern sector during this flight. During flights II and III, distribution changed, and hot spots were concentrated inside vineyards (Figs. 6 and 7). In particular, the localization of high-density areas was very similar for the two flights within the same year. In 2005 and 2006, hot spots where located in V_1, V_3, V_4, V_5, and V_6, although they were less evident

during flight II than flight III. The presence of *L. botrana* beyond vineyards was limited in both years.

Discussion

The correlogram analyses provided some information on spatio-temporal distribution of *L. botrana.* In both years, the distribution of *L. botrana* males was aggregated in the area, as indicated by values of *k* that suggest strong autocorrelation between samples. The estimated range of correlograms represents the radius of a circle within which the samples are autocorrelated and can be used to evaluate the aggregation area of *L. botrana* in the field (Liebhold et al. 1993). Our results showed a certain variability of values from one week to another, but mean ranges of weekly models in both year were comparable and similar to the mean of single flights models (126 ± 20 m) calculated using semivariograms. An aggregated distribution of larvae in the field was reported by Badehnausser et al. (1999) and Ifoulis and Savopoulou-Soultani (2006), who suggested that oviposition behavior and site seeking of females likely explained this spatial aggregation. Peláez et al. (2006), using pheromone-baited traps, found an aggregated distribution of males, but larger semivariogram ranges, varying between 280 and 300 m. From an applied perspective, the information we obtained can be used to develop *L. botrana* sampling plans, suggesting an optimum trap distance in the field (Bacca et al. 2006): in our case, and adopting a conservative approach, pheromone-baited traps should be placed ≈115 m apart. Thus, to sample over an area of 42,000 m², ≈2 traps/ha would be required.

In addition to the data presented in Table 1, contour maps also showed that the spatial distribution of *L. botrana* was not limited to vineyards and that its presence is high, particularly inside olive groves during
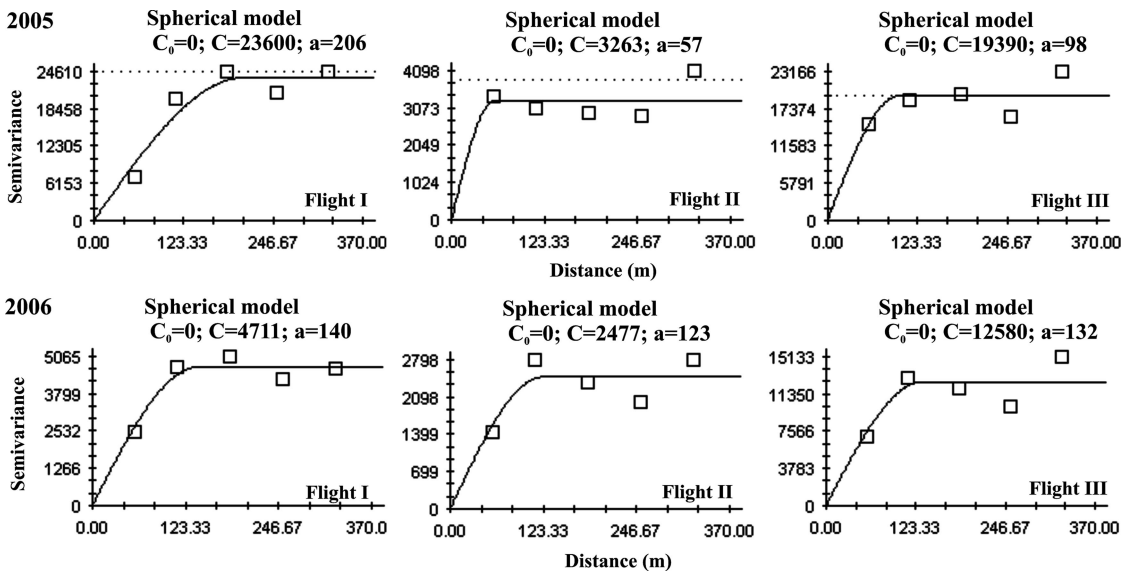
Fig. 5. Semivariograms and asymptotic models of the pheromone trap caches of *L. botrana* flights during 2005 and 2006.
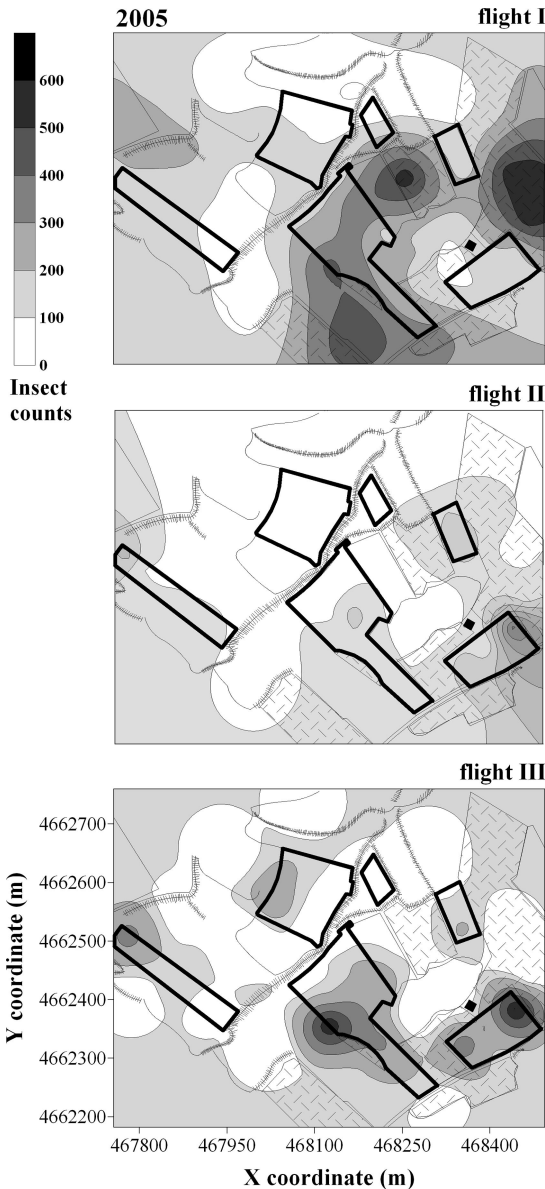
Fig. 6. Contour maps of adult male *L. botrana* distribution obtained by kriging procedures applied to single flight trap counts in 2005. Bold lines outline vineyards. Dotted areas outline olive groves.

Fig. 7. Contour maps of adult male *L. botrana* distribution obtained by kriging procedures applied to single flight trap counts in 2006. Bold lines outline vineyards. Dotted areas outline olive groves.

flight I. More interestingly, this distribution changes radically during the season: at the beginning, hot spots were positioned inside olive groves, and during flights II and III, they were concentrated in vineyards.

The ability of *L. botrana* to develop on olive trees is well known (Stavridis and Savopoulou-Soultani 1998) and was also observed in the experimental area (unpublished data). In Greece, field and laboratory experiments showed that, for developing *L. botrana* larvae, olive inflorescences were as suitable, and under certain conditions, more suitable, as host plants than vine inflorescences, and that both were equally ac-
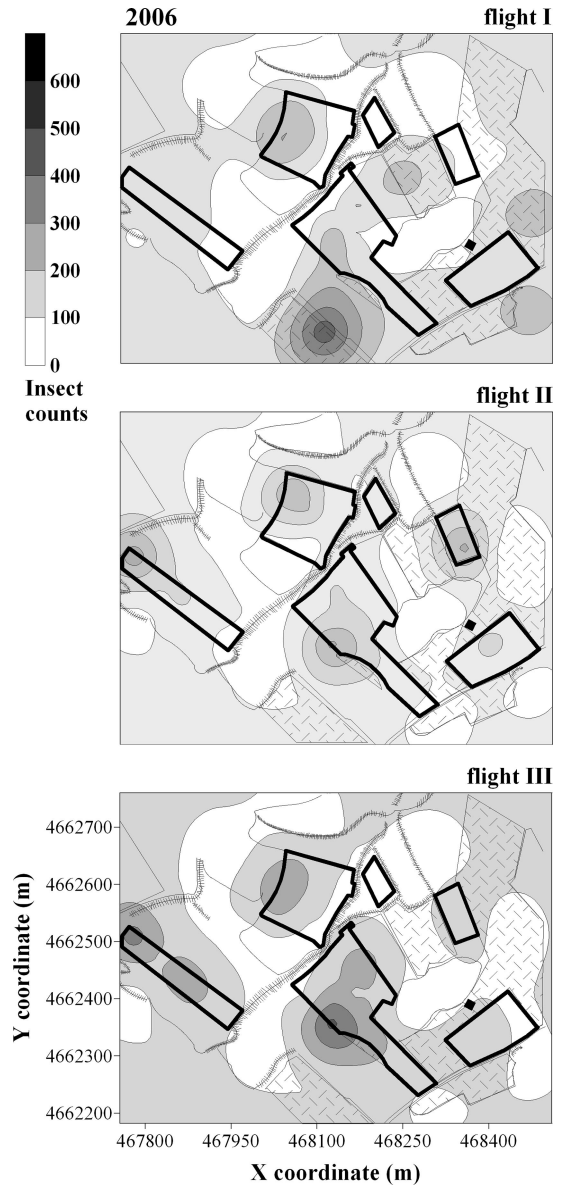
cepted for oviposition (Savopoulou-Soultani and Tzanakakis 1987, Savopoulou-Soultani et al. 1990). However, it has been shown that *L. botrana* is attracted by volatiles from grapevine berries (Tasin et al. 2005), but it is not known the role that olive volatile compounds exert on adults.

In this study, the highest densities of adult males during flight I in both 2005 and 2006 were in or on the border of olive groves (Figs. 6 and 7), and although counts from olive groves decreased during subsequent flights, the male trap catch still remained reasonably high. These observation suggest that olive may serve

as a primary overwintering host outside vineyards. In many Mediterranean areas of central and southern Italy, vineyards and olive groves are two of the more common types of cultivated crops and frequently are in close proximity to each other. In these cases, *L. botrana* can disperse throughout the landscape, posing challenges to growers who may manage populations within the vineyard, but who also may leave potential refuge areas such as olive groves unmanaged. Savopoulou-Soultani et al. (1990) speculated that olive groves represent an infestation focus for neighboring vineyards, especially in spring during flowering. On the basis of our results, we assume that part of the first generation of larvae, produced by adults of the first seasonal flight, develops on olive; then emerging adults move toward vineyards, contributing to the second larval generation that develops on grape.

The presence of *L. botrana* males was observed in uncultivated fields, but never in high densities. Nevertheless, this suggests that some host plants can be present in these uncultivated areas, thus representing an alternative source of infestation. Considering the polyphagy of *L. botrana,* the occurrence of vegetation constituting alternative reservoirs of the species, such as *D. gnidium,* regarded as the native host plant (Maher and Thiéry 2006), should always be evaluated in vine-growing areas. However, it is also possible that traps intercepted males moving around and responding to the drift of pheromone; in this case, data from traps located immediately outside of the vineyard may provide an incomplete picture of the spatial pattern. Movement of insects, and in particular tortricid moths, between wild or cultivated habitats has been reported by several authors (Hoffman and Dennehy 1989, Woiwod and Stewart 1990, Barrett 2000, Sciarretta et al. 2001, Botero-Garcés and Isaacs 2003, 2004, Sciarretta and Trematerra 2006). Unfortunately, *L. botrana* male movement cannot be directly detected using contour maps, and specific information of this phenomenon in the literature is scarce. Boller (1993) conducted mark–recapture trials with males within vineyards and observed that 87 and 96% of released individuals were captured <50 and <100 m, respectively, from release points. Similar results were obtained by Schmitz et al. (1996), who noticed that displacement of adults inside vineyard rarely exceeded 80 m. Thus, traps placed at least 80 m from the edge of the vineyard, especially for monitoring areas where host plants are scarce or nonexistent, may provide a better estimate of the spatial distribution of *L. botrana.*

Our results showed that a large proportion of the adult population of *L. botrana* is in areas outside of those usually targeted by management programs. The increased use of monitoring tools such as pheromone-baited traps and control techniques that modify insect behavior, such as mating disruption, attract-and-kill, and auto-confusion, requires a thorough evaluation in the timing and placement of traps and dispensers, especially at the beginning of the season. It is thus highly recommended to consider the whole landscape, with particular attention to olive crops in Mediterranean agro-ecosystems. In particular, when at-

tempting to identify sources of infestation, monitoring traps can be deployed to intercept immigrating moths, as well as to measure the density of the resident population. In addition, in IPM programs, it is possible to suggest precision farming control measures such as including more dispensers on the borders at risk, extension of the disrupted area out of the vineyard to include nearby olive trees, positioning additional traps as barriers to the entry of males into the vineyard, and creation of land strips devoid of host plants among vineyards and olive groves. Further studies should focus on the relationship between grapevine damage levels and the distribution of neighboring olive plants to better quantify their potential economic impact on vineyards.

Acknowledgments

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