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New approaches for the management of European grapevine moth (*Lobesia botrana* Den. & Schiff.)

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Abstract. European Grapevine Moth (EGVM), *Lobesia botrana* (Den. & Schiff.) (Lepidoptera: Tortricidae) is the key pest of grape in Turkey. It damages grape berries directly and requires strict control measures producing 3 or 4 generations per year. Since the '80s, farmers often preferred chemical control with organophosphorus insecticides against the pest because it is wieldy, very effective and cheap. Tendency to use environmentally friendly pesticides began at the beginning of the nineties because chemicals sprayed next to grape harvest threaten environment and consumer health, causing residue problem in export. Consequently, a bioinsecticide, *Bacillus thuringiensis* Berl., was put into practice against the pest. Forecasting System timing according to the larvicides against EGVM was reviewed as a result of the registration of an ovicide at the end of nineties. Modifications have been made in standard biological efficacy test method and Forecasting System taking the biological stages of EGVM into account to get optimal results from ovicides. Mating disruption and auto-confusion techniques against EGVM were tested and put into practice for the first time in the Aegean Region to decrease insecticide applications. Since 2005, mating disruption has been gradually preferred by the growers and firms because it is very effective and easy to apply.

1. Introduction

Viticulture is one of the important agricultural occupations in Turkey. Seeded, seedless, wine and fresh grape has a great significance in export as well as domestic consumption with its production amount of 3.5 million tons in 400 thousand-production area. The Aegean Region ranks first covering 35% of the total area [1]. Almost 80% of 260 thousand-ton-seedless dried grape, as an average of the past decade, is exported to different countries mainly Europe [2].

European Grapevine Moth (EGVM) (*Lobesia botrana* Den.-Schiff., Lepidoptera : Tortricidae), directly causes crop losses through an infestation rate varying 46,6–92,2% if protective measures are not employed [3].

EGVM is the key pest since it is available almost in every vineyard annually, causing damage directly on grapes, producing 3–4 generations per year and requiring preventive measures [4].

Since the '80s, vine growers often preferred chemical control with wide spectrum insecticides against the pest because it is wieldy, very effective and cheap.

However, chemicals sprayed next to grape harvest threaten environment and consumer health, and national economy causing residue problem in export, and suffering from returning goods, frequently.

Reducing pesticide consumption and focusing on environmentally friendly control methods are among the priority targets of national research institutions in Turkey when choosing research subjects. National Integrated Grape Pest Management Project has been conducting since 1995. Bornova Plant Protection Research Station (BPPRS) took on the coordinatorship of the Project [5].

In this article, environmentally friendly management of EGVM is approached in the light of information obtained from research studies in the frame of the project by BPPRS and put into practice in the Aegean Region.

1.1. Studies conducted in the Aegean Region

Concerning pollution and hazardous side effects of pesticides, integrated pest management has gradually been an important issue in the world at the end of eighties. In parallel with these developments, tendency to use environmentally friendly pesticides began at the beginning of the nineties in Turkey.

1.1.1. Studies on Bacillus thuringiensis

Biological efficiency tests and timing of applications of bioinsecticide, *Bacillus thuringiensis* Berl., against EGVM were conducted in vineyards by researchers from BPPRS between the years of 1991 and 1994.

B. thuringiensis var. *kurstaki*, the entomopathogen bacteria, was too far to suppress the pest when applied alone in the first year of the study. Possible reasons for failure have been discussed in the frame of the study in detail. Bio insecticides with *B. thuringiensis* are slower than pyrethroids having knockdown within a few minutes after application or organophosphorus insecticides (OPs) having different mode of actions such as contact, ingestion and/or vapour in the same compound. Bacteria must be

first ingested by larvae. It then requires 1 or 2 days to kill them. On the other hand, bunches of Seedless Sultana, the most common grape variety grown in the Aegean Region, get bigger and more compact because of the Gibberellic acid applications and irrigations until July and August when the third and fourth generation larvae of EGVM coincide. Consequently, young larva hatching from egg can easily enter into grape berry within 1 or 2 h even sometimes it does not face with the sprayed surface. Better coverage of *B. thuringiensis* has been provided on waxy layer of grape berries after its tank mixture with 1% granulated sugar as well as stimulation of larval feeding by attracting them to sweet surface and successfully suppression of EGVM at the rate of 90% [6].

The second important factor providing higher efficacy is better timing of sprayings. Available Forecasting System was able to determine the first eggs laid in vineyards for the growers to use classical contact- or ingestion-efficient insecticides against larvae. Both regional and national Forecasting System has been set for growers to apply insecticide within 1 and 3 days when the first larval hatching is expected since the '80s. This System helped to define the best timing for sprayings with *B. thuringiensis*. Differing from OPs or pyrethroids sprayed together with first larval hatching, spraying *B. thuringiensis* at the dark head capsule stage of EGVM eggs provided the highest efficiency since larvae would hatch within 24 h and face directly to berries covered with bacteria. As a result of the study by BPPRS, registration of *B. thuringiensis* against EGVM helped organic grape growing that is common in the Aegean Region [6]. Nowadays, *B. thuringiensis* var. *aizawai* is also registered against EGVM as well as *B. thuringiensis* var. *kurstaki*. Not only organic grape growers but also the growers following conventional and integrated crop management principles are preferring *B. thuringiensis* in the sprayings next to harvest to protect human and environmental health and to reduce residual problems.

1.1.2. Studies on insect growth regulators

In the frame of the principles of IPM, low toxic and suitable pesticides are selected when chemical control is needed. Upon registration of an ovicide insect growth regulator at the end of the '90s, available Forecasting System which announces according to the larvicides has been reviewed during the studies of Integrated Grape Pest Management Project in the Aegean Region in 1997.

Previous research studies conducted in Turkey and in the World have been evaluated, reviewing pest biology in the lab and the field. Benzoylureas, insect growth regulators (IGRs), inhibit chitin synthesis of insects. If it is applied before egg laying, it stops embryonic development and prevent larval hatching. Even if the eggs hatch, it stops larval development and causes death in young larvae. Moreover, females touching chemical-covered surface are effected and their eggs are sterilised. Aiming at the utilization from all mode of actions of benzoylureas at the same time, spraying before egg laying in the field has been targeted. It is possible to apply these IGRs once in any generation because the duration is long enough. However, by some reasons such as absence of a clear interruption between second and third flight periods of adults, shortness of period between maximum adult flight and first larval hatching in third generation [7], overlapping after third generation and long pre-harvest interval of the IGR, the most suitable timing has been decided as the period before egg laying of second generation.

As known, larvae hatching from eggs laid by second generation-females damage unripen berries. Beginning and fluctuation of each flight period is monitored by pheromone traps in the field. Adults of second generation are generally observed in early June in the Aegean Region. Flight period of first and second generation are definitely interrupted from each other and appears by running out of captures in traps at the end of May. Duration between the first adult capturing and flight peak of second generation is 16 ± 1 d (7–28), whereas required period between flight peak and first egg is $(-1.5) \pm 1$ d $[(-14) - (+4)]$ [8]. Successful results have been obtained when an ovicide IGR has been applied 13–15 days later then first adult capture in traps and before egg laying during the studies of Integrated Grape Pest Management Project in the Aegean Region in 1997 and 1999 [9]. Consequently, Forecasting System has been modified to be able to announce application times for ovicides as well as larvicides, practically. Since incubation periods (day) of EGVM eggs in certain temperatures are known [10], these periods have been converted into degree-day and extracted from cumulative degree-days used for larvae. Accordingly, cumulative degree-days until egg laying in each generation have been obtained. Additionally, modifications related to biological criteria of EGVM have been made in national standard biological efficacy test method to be used in the registration of ovicides. Table 1 compares biological criteria used for timing ovicides and larvicides in Forecasting System.

1.1.3. Studies on biotechnical methods

Mating disruption (MD) technique is a biotechnical method that aims at preventing males from finding unmated females by saturating the atmosphere to artificial pheromone of the species through the use of sexual pheromone loaded dispensers. Thus, the method leaves the females unfertilized and incapable of laying viable eggs.

Inspite of the fact that the idea was born in 1963, research studies on mating disruption have gradually increased since the '80s [11]. The technique has the widest as an alternative to chemical control with an acreage of 600 000 ha-application area in the World in 2002. The surface applied by pheromones is being increased [12]. MD was tested and put into practice in consideration of high efficiency against EGVM in countries such as Germany, Switzerland and Italy [13–15]. Research studies are still conducted to increase the efficiency in the World [16].

The Ministry of Food, Agriculture and Livestock has assigned BPPRS to focus on biotechnical methods against insect pests [17]. Within this context, BPPRS has always been the pioneer institution in carrying researches on the efficiency of biotechnical methods. Mating disruption, one of the biotechnical aspects, was tested against EGVM and put into practice for the first time in the Aegean Region to decrease insecticide applications in Turkey.

Table 1. Criteria used for timing ovicides and larvicides in Forecasting System against *Lobesia botrana*.

Criteria	Gen.	Ovicide	Larvicide
Flight	all	Persistence of captures	Peak
Cumulative Degree-Days	1	95–100 d-d	120 d-d
	2	450–460 d-d	520 d-d
	3	970–980 d-d	1047 d-d
Grape Phenology Stages	1	Separated floral buds	Separated floral buds
	2	Fruit Set	Unripen berry
	3	Beginning of Maturation	Beginning of Maturation
Monitoring eggs	all	Before egg laying	Dark head capsule stage

Isonet-L pheromone dispensers have been registered in Turkey in 2003 [4]. Dispensers having 172 mg pheromone in each are installed in the vineyards against EGVM at the end of March–early April as soon as the first adults are captured in traps. It must be applied in every row at 7 m intervals and in border at 2 m intervals [18]. The technique can also be applied by RAK 2 PRO dispensers having 400 mg pheromone in each in every row at 6.5 m intervals and in border at 2 m intervals. It is vital to apply MD in a surface bigger than 16 ha if the application area is surrounded by neighbour vineyards [19]. If MD is applied in the same area at least two consecutive years, the number of sprayings against EGVM generally decreases or does not necessary anymore [4].

Research studies continued to spread and adopt the technique in wider areas. MD application area gradually increased by growers and stakeholders who adopt environmentally friendly agricultural systems especially organic agriculture since 2005 [20]. For example, the total application area was only 550 ha in Manisa in 2009 [21]. Upon subsidization of biotechnical methods by the Ministry of Food, Agriculture and Livestock, the total surface reached to 5 thousands ha in 2012.

Relations between the efficacy of mating disruption technique against EGVM and canopy conditions of different trellising systems have been investigated in Sultani Cekirdeksiz vineyards in Manisa Province between the years of 2003 and 2006. Infestation rates, leaf densities and leaf area indexes were compared in the vineyards trained as Big T, Y and Wall. The lowest infestation rates were generally determined in the Y trained vineyard in third and fourth generations of EGVM. Y system could be in favour of mating disruption technique due to absorption of higher pheromone amount in its higher leaf area [22]. It is also unfavorable for the pest due to lower internal humidity and higher internal temperature during critical period of egg lay. If "T system is available in the vineyard to be applied by pheromones, leaf removal is strongly advised to provide better illumination and higher temperature + lower humidity conditions at the center of vine canopy, which is unfavorable for the pest.

Auto-confusion is a brand new biotechnical method in the control of Lepidoptera species in orchards and stored products. It depends upon treatment of target area by sexual pheromone after mixing with electrostatic powder. When males attracted by pheromone and touch the dispensers, their bodies and antenna are fully covered by electrostatic powder that hinders those finding females and copulating with. The individuals infested with pheromone confuse other males in the population by false trail. Moreover, infested ones are not comprehended as real male anymore. They are rejected by other females and followed by clean males in the population [23].

Auto confusion has been tested in Manisa against EGVM in 2007 and 2008. It may be used at the dose of 180 Exo dispensers per ha at 60 day-interval. If the infestation rate exceeds 5–6%, it should be combined with preferably *B. thuringiensis* once or twice to suppress the pest. It was considered that Exo dispensers could drop number of sprayings from 4–5 to 1–2 in the Aegean Region where higher daily temperatures and population density of EGVM, longer flight period and more generations are available [24]. Exo dispensers were registered in Turkey in 2012.

2. Conclusion

Management of EGVM was solely depended upon chemical control during '80s in the Aegean Region where grape growing is the widest. However, the Region has been the model in terms of contracted agricultural applications such as organic agriculture, integrated production and good agriculture practices, using the opportunity of being leader in grape production in Turkey. Now, biological and biotechnical methods are mostly preferred and widely spread against EGVM. Subsidization of growers preferring them by the Ministry of Food, Agriculture and Livestock will enhance the application area of environmentally friendly control methods. Different research projects of BPPRS are in progress under national Integrated Grape Pest Management Project to enhance biological and biotechnical control methods and decrease pesticide consumption.

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