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Mating Disruption of Grape Moths with Pheromone as a Pest Control Strategy in Vineyards

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ABSTRACT

This report is concerned with mating disruption, by pheromones, of the grape berry moth, Endopiza viteana (Clemens), the grape vine moth Lobesia botrana (Schiff.) and the honeydew moth Cryptoblabes gnidiella Mill.

In early investigations on the grape berry moth (GBM), Endopiza viteana, the sex pheromone was identified as Z9-12:Ac. For about a decade this isomer containing ca 4% E isomer was used in traps and in pheromone formulations evaluated for control.

Recent research leading to identification of another pheromone component (Z11-14:Ac) is reported herein. The blend of one part Z11-14:Ac and nine parts Z9-12:Ac greatly increased the attractiveness of traps.

In a .19 ha plot a single treatment of the pheromone-rubber septa formulation, 100 mg/vine was very effective in disrupting the orientation of laboratory-reared males released over a period of 63 days after treating. At weekly intervals male disruption ranged from 93 to 100%. Live two-day old virgin females (laboratory reared) were ineffective in attracting male moths to traps in treated and check plots.

Two of the four pheromone-releaser formulations gave 100% disruption. One was 100 mg pheromone/rubber septum/vine, which was applied five times. The other was 90 mg pheromone/20 cm length of polyethylene tubing (Type G Releaser), two/vine/application, applied three times. The rubber septum formulation in spite of the high degree of male disruption failed to give satisfactory control. The pheromone-Type G Releaser schedule of 3 treatments was very effective

in disrupting wild male moths and at harvest the schedule gave a promising degree of control.

Grape vine moth (GVM) pheromone, (Z,E)7,9-dodecadienyl acetate, released in vineyard from rubber septa and from Herculite polymeric vinyl laminates reduced the number of males caught in pheromone or virgin female traps. Release of the pheromone from flax string (30 mg/m), stretched along vine rows, gave better results but did not completely inhibit male orientation to the traps. Spray of Accurel dust impregnated with the pheromone caused complete disruption of male orientation but only for one or two days. Compounds other than (Z,E)7,9-dodecadienyl acetate had a lower disruption effect. It is speculated that the GVM pheromone contains minor, as yet unidentified, component(s) which are necessary to cause complete disruption of intersexual communication in the field.

Mass trapping of GVM males can reduce damage and save on insecticides application but the method is not economical as yet.

Disruption of sexual communication in the honeydew moth, by releasing sex attractants in the field, was demonstrated but more tests are needed.

OBJECTIVES OF THE RESEARCH

The main objective of this research was to develop a strategy of pest control for the grape moths that utilize a specific innocuous pheromone in place of carbamate and organophosphate insecticides. The means employed: permeation of the field atmosphere with the pheromone to disrupt the normal mating communication system; evaluation of different releasers for efficiency in disrupting male orientation to synthetic attractant traps and to females, at various application rates and intervals; application of the mating disruption technique in larger field trials in which is determined from data on mating disruption and on insect infestation levels and crop damage. The development of the mating disruption technique for the grape moths will add to the general body of knowledge of this technique.

The proposed research program is a logical extension of current research programs in our Institutes, in Geneva, N.Y. and Bet-Dagan, Israel, and represent a major effort at using this method for fruit insect control. The development of this method of control is also compatible to the goal of both Institutes in developing pest management practices that use a minimum of insecticide sprays.

INTRODUCTION

The grape berry moth (Paralobesia viteana) (Endopiza viteana) is found feeding the fruit of wild as well as cultivated grapes growing in United States east of the Rocky Mountains. It is also found in the grape producing area of Ontario, Canada. This species is usually abundant enough to warrant the use of chemical control programs of 2 or 3 or even 4 applications in commercial vineyards.

With the identification and synthesis of the female sex pheromone a successful method was developed for monitoring male moths activity. It was accomplished with the development of a sticky trap that could be charged with a dispenser containing the female sex pheromone. This phase of research on pheromones was followed by investigations on control by mating disruption that occurred when a high atmospheric concentration of the pheromone was maintained. Control by this technique offers some advantages over insecticides. At least there would be a reduction of the problem of toxic residues on crops and also, there would be less environmental contamination resulting from continued use of insecticides.

Presented in this report are the results from tests attempting to increase the attractiveness of the compound Z9-12:Ac, originally identified as GBM female sex pheromone, by blending it with Z11-14:Ac; tests determining the longevity of a single application of the pheromone blend under field conditions and tests using several units as releasers for the GBM pheromone blend.

The grape vine moth, Lobesia botrana, is found in the Mediterranean basin, South Russia and Central Europe. In Israel the larvae feed on flower buds, inflorescences and on grape proper. Beside

the direct damage it causes development of the mold Botrytis. On the average 6-7 treatments of insecticides are applied every season to control this pest. The honeydew moth, Cryptoblabes gnidiella, was found in the Mediterranean basin on a variety of hosts including grapes. Although it is becoming an important late season pest of grapes no study has been done on its phenology and control in Israel vineyards. Following the identification and synthesis of the grape vine moth pheromone monitoring system was developed for this moth but little research on mating disruption of the moth was done. Practically nothing was known on monitoring and mating disruption of the honeydew moth. The present report deals with male mass trapping and various release methods for pheromonal control of the grape vine moth. Research on the honeydew moth was focused on seasonal trapping of males.

MATERIALS AND METHODS

Grape berry moth

Sex pheromone blends

An important phase of the investigation on the mating disruption technique as a means of GBM control were tests aimed at improving the attractiveness of pheromone traps used to monitor male moth activity. The original investigation on identification of the GBM sex pheromone revealed that the compound was Z-9-dodecenyl acetate (Z9-12:Ac) (Roelofs et al. 1971). The data from male monitoring trials suggested that the most competitive trapping system was 10 to 30 mg of Z9-12:Ac with ca 4% of the E isomer on a rubber septa (Arthur H. Thomas Co., Philadelphia, PA) and a sticky trap, Pherotrap^R 1C (Zoecon Crop., Palo Alto, CA) (Taschenberg et al 1974). This combination in earlier studies was used in male population monitoring and control studies for a limited time.

The recent trials were conducted in 1982 and 1984 using rubber septa to dispense the attractant blends from Zeocon^R 1C monitoring traps. During 1982 the treatments were evaluated against males that were reared in the laboratory under these conditions: temperature, $25.5 \pm 1.6^{\circ}\text{C}$ and a light regime of 16h light and 8h dark and the larvae were fed on natural food, grapes. In 1984 the trials were conducted on a wild male population. Each plot was 13.5 m (five rows of grapevines) wide and 14.4 m (six grape vines) long. One trap was hung at the center of each plot on the top trellis wire on row 3 and between vines 3 and 4 of the 6 vine row. The treatments were replicated four or five times.

Recent studies on male GBM pheromone composition revealed the presence of Z-11-tetradecenyl acetate (Z11-14:Ac) in addition to Z9-12:Ac (unpublished data by L. Bjostad & W.L. Roelofs).

Longevity of sex pheromone treatment

During 1983 a test was carried on to determine the longevity of a single pheromone application for disrupting male orientation to monitoring traps. The formulation of pheromone selected was a combination of rubber septa, as the pheromone releaser, each containing 100 mg of the 9:1 blend of Z9-12:Ac + Z11-14:Ac, respectively. One releaser was used per vine and the treatment was made in this manner: The septa were spaced 2.4 m apart in the row, in the vicinity of the head of each vine and at a height of 1.6 m above the ground. Grape tie wires were used to fasten the septa at the designated position on the vine or on the top trellis wire. The plots, both treated and check, were ca 0.2 ha; ca 1/2 the area of plots in which GBM control experiments with pheromone were conducted. Also of interest here is whether a plot of this size, 288 vines, would be satisfactory for conducting preliminary male disruption trials. The check and treated plots were 600 m apart.

In the 1983 trial the pheromone treatment was applied on 7/14 and from this time until 9/15, a period of 63 days, male moth activity was monitored in both treated and check plots with six traps in a plot. Each trap, Pherocon^R 1C, was charged with a rubber septum containing 100 ug of the pheromone blend defined above and the same septa were used for 63 days. The distribution of these traps within the 16 row

plot was according to this arrangement. They were located in rows 8 and 9 and between these vines 3 and 4, 9 and 10 and 15 and 16.

Another procedure of monitoring involved Pherocon^R 1C traps, each of which was charged with five 2-day old virgin female GBM adults: ten of these traps were used per plot. The location of the traps in the 16 row wide plot was as follows: in rows 2 and 15 there was only one trap in each row, and two traps in each of these rows, 4, 6, 11 and 13. The female moths supplying the attractant in a trap were enclosed in a cage made in this way from a 40 dram (4.5 x 8 cm) plastic vial with a snap-on lid in which there was an opening through which moths were easily introduced in the cage. Two rectangular shaped openings (4.4 x 5 cm) were cut in the wall of the vial at a position of 2.45 cm above the vial bottom. The openings were covered with Saran (Chicopee Mfg. C., Cornelia, GA) fabric (32 x 32 construction Style, 6103200). In the bottom of a cage there was enough space to accommodate a cellulose sponge disc (2.5 cm thick and 4.4 cm in diam.). The purpose of the sponge was to provide moisture for the moths. Traps using females moths for the attractant were introduced in the plots on 7/14, the same day as the pheromone treatment was applied, and thereafter the moths were replaced on these dates, 7/19, 7/25, 8/1, 8/8, 8/15, 8/23, 8/29, 9/6, and 9/13.

The live male and female moths used throughout the test period were reared under laboratory conditions on grapes (Taschenberg, 1969). Releases of males were made on 40 of the 63 days of experimentation and on each day of release the same number were freed in the check and treated plots. Between 7/14 and 9/15 a total of 1216 males were liberated in each plot.

A test was conducted using Herculite polymeric vinyl (Herculite, Health Chem. Corp., New York, N.Y.) laminated flakes, each (.63 x 1.27 cm) as a pheromone releaser under field conditions. Only a single treatment was made using one charged flake, 4.37 mg of synthetic pheromone, per vine. Details of the procedures, such as plot size, location of monitoring traps charged with either live females or synthetic pheromone and distribution of the releasers on either the top trellis wire or in the head of the grapevine were presented earlier in this section describing the evaluation of single treatment of rubber septa as the pheromone releasers.

Disruption and Control Experiments

Field tests to evaluate mating disruption as a means of control were conducted in commercial Concord plantings during 1982, 1983 and 1984. The formulations of releaser and pheromone blend tested are listed in columns 1 and 2 in Tables 6 and 7.

The test plots were at least 0.4 ha; an area with ca 600 grape vines spaced 2.4 m apart in the row and 2.6 m between rows. An effort was made when laying out plots to keep their shape approximately square. The check and treated plots were separated by a distance of at least 600 m. Rows parallel and adjacent to the test plots were heavily treated with insecticide. The purpose was to minimize moth migration to the test blocks.

The releasers charged with pheromone were applied manually to the vines. One or two of the units were used per vine per application and were placed either in the head of the vine or on the top trellis wire at a spacing of 2.4 m and a height of ca 1.6 m. From three to five

treatments were applied per season; with the five-treatment program two applications were against male moths emerging from overwintering pupae and three applications were directed at moths emerging from first brood pupae. At the time that each fresh treatment was made the releasers from an earlier treatment or treatments were not removed from the test plots.

By following the manual procedure of treating there was the elimination of the doubt about the location of releasers on the vine and the number of releasers applied per plot.

The effectiveness of the formulation of pheromone and releaser for GBM control was assessed by two methods. One was to determine the number of male moths able to orientate to monitoring traps (Pherocon^R 1C) charged with a dispenser containing a known amount of the pheromone blend. Only two such traps were operated in the center row or center two rows of a plot. These traps were checked and cleaned about three times a week. Monitoring was initiated at the time the first pheromone application, ca May 20, and continued for about 61 days at which time these traps with dispenser were discarded and replaced with new traps and dispensers freshly charged with pheromone.

The other procedure for assessing the performance of the various pheromone formulations was to determine by actual examination and count the difference in amount of GBM injury to grape berries on clusters picked in the treated and checked plots. The clusters used for this purpose were picked from sub-plots, each plot was 20 vines in length and limited to one row. At harvest ten clusters were picked at random, per vine, and this was repeated on 10 vines of the 20 vine plot.

During 1982 two potential pheromone releasers were tested in the experiments to evaluate the mating disruption technique for GBM control. The releasers selected for one test were white celcon polyoxymethylene (FRL, Albany International Co., Norwood, MA) hollow fibers 8 ml by 1.25 cm in length. These fibers were supplied on strips or tabs of supporting tape. There were ten hollow fibers on one side of the strip and the other side the strip was coated with a sticky material which facilitated the application of treatments. By this means the fibers could be held in a selected position on the grapevine or trellis. Each strip or tab with ten hollow fibers contained 3.2 mg of a mixture of 88.2% Z9-12:Ac, 1.8% Z11-14:Ac and 10% hexane. Ten fibers (one strip) was used per vine per application. A total of five applications were made, 5/25, 6/18, 7/30, 8/12 and 8/27. The check and treated plots were each about 0.4 h. The traps, two/plot, for each treated and check plot, used to monitor male activity were charged with 30 mg of the blend (5:1) Z9-12:Ac and Z11-14:Ac. Polymeric vinyl laminated flakes or units were also tried as pheromone releasers in a commercial vineyard where annually there is moderate to severe GBM inuury to the fruit at harvest. The flakes were .63 x 1.37 cm and were charged with 4.2 mg of the female GBM sex attractant, Z9-12:Ac. One flake was used per vine; this totaled 1500/ha; each spaced 2.4 m apart in the row. Pheromone was applied at the rate of 63 g per ha per application. Each plastic flake was attached to the head of the vine or on the top trellis wire with a grape tie wire. Male moth activity was monitored in each test plot (treated and checked) with two sticky traps; each was charged with a rubber septum containing 30 mg of the pheromone Z9-12:Ac. This

operation began on the day that the first treatment was applied 5/27, and continued until 9/20. The traps and dispensers were replaced only one time. A total of five treatments were applied; dates of application were 5/27, 6/22, 7/29, 8/13 and 8/25.

Due to the success using rubber septa as a dispenser in the monitoring trap phase of the investigation on pheromones it appeared to be a worthwhile pheromone releaser candidate for testing in the field in 1983. The septa were 1.5 mm long x 8 mm diameter on the open end and 5 mm on the closed end. Each septum contained 100 mg of the pheromone blend (91%) Z9-12:Ac plus (9%) Z11-14:Ac. The 1983 field test was one in which the pheromone was applied at a rate higher than those used in earlier tests; 100 mg/vine or 150 g/ha. The treatment with the formulation of rubber septa and pheromone blend was applied five times; the 1st on May 23, the 2nd, 3rd and 4th at intervals of 25 days and the final on Aug. 30. One charged septum was used per vine and at a spacing of 2.4 m in the row. Grape tie wires were used to fasten the rubber septa in the heads of vines. When a treatment was applied the septa from a previous application or applications were not removed.

Rubber septa each containing 100 mg of pheromone was employed as the pheromone dispenser for the monitoring traps, Pherocon^R 1C. Two such traps were used in each treated and checked plot. These traps were placed in the plots when the first pheromone treatment was applied and operated from this time until mid- or late-July when they were replaced by new traps and rubber septa freshly charged with 100 mg pheromone.

The study on mating disruption as a method for controlling GBM was continued in 1984. The sex pheromone releasers were pieces of polyethylene tubing each 20 cm long and 3 mm wide. Imbedded in the wall of each tube is a piece of fine wire, the same length as the tube. The application of the units to grape vines and/or trellis wire was a relatively simple operation. Two such releasers were placed 1.2 m apart on each vine. These pheromone releasing units were developed and supplied for experimental investigations and are known as Type G Releaser (Shin-Etsu Tube Releaser, Shin Etsu Chemical Co., Tokyo, Japan).

The pheromone blend used to charge the releasers was Z9-12:Ac, 85%; E9-12:Ac, 5% and Z11-14:Ac, 10% and 90 mg of this blend was used in each releaser. Only three applications were made; two less than the number used in other years. The first application was on 6/13 which is considered to be about three weeks late when compared with initial application dates of other years. The second and third applications were made on 7/18 and 8/1, respectively. Male moth activity in the plots, treated and check, were monitored with two Pherocon^R 1C traps per plot.

The rubber septum pheromone dispenser for each monitoring trap was loaded with 100 ug of the same blend as used in the releasers for treating plots. The monitoring of male moth activity was initiated on June 13 and continued to Sept. 24. The two traps used for this purpose were placed in the center row of a plot and 157 m apart in the row.

The treated as well as the checked plots were treated on July 2 and July 20 with the mildewcide, Treadimefron (Agricultural Chemicals

Division, Mobay Chemical Corp., Kansas City, MO) at rate of 56.6 g (2 oz) of formulation/0.4 ha as a concentrate spray mixture. No other pesticide was applied in either plot.

Grape vine moth

Insect

Culture of the grapevine moth (GVM) was kept in a ventilated room with an ambient temperature of 25 ± 1 C and under artificial 14:10 day:night regime. Larvae were fed an artificial diet consisting of (% fresh weight):dry vine leaves 9.2%; corn seeds 3.7%; yeast 3.4%; wheat bran 3.2%; ascorbic acid 3.7%; benzoic acid 0.15%; nipagin 0.15%; canned vine juice 32.1%; agar 1.8% and water 45.8%. The diet was prepared as follows: the corn seeds were soaked in 1/5 of the amount of the vine juice for 24 h and then ground in a blender. The agar and water were heated until the solution became clear. The vine juice, the corn blend and a mixture of the dry ingredients were respectively added to the agar while blending. The food was then poured into suitable dishes and allowed to cool and gel. It was kept in a refrigerator until use.

The following procedures were taken in rearing GVM: Eggs were obtained by putting forty freshly emerged male and female moths in a closed 1/2 l plastic jar with two screened holes for ventilation. A small bottle of sucrose solution with a cotton wick was first placed in the jar as food for the adults. The moths laid their eggs on the inner walls of the jar. After 6 days the moths were discarded and the jar was washed with water and then with 70% solution of ethyl alcohol. The jar was then placed upside down for 6 days on

the bottom of a larger rearing jar (15 cm diam. by 8 cm. high) which contained a small amount of larval food in the center. The hatching larvae crawled down and settled on the food. At the end of 6 days the oviposition jar was removed, more food was added to the rearing jar which was then closed with a plastic covering with a 4 cm screened hole in its center, this hole was blocked for 10 days by putting a solid object on it to preserve moisture. Only after 10 days was the object removed to allow ventilation. Larval food was added if needed at any time during larval growth. When the larvae were about to pupate the rearing jar was lined with corrugated paper. The larvae pupated on the paper. Soon after emergence of the adults - 300-500 from each rearing jar - they were anesthetized with CO₂ and were transferred to oviposition jars. Under these conditions the duration of a generation was about one month. To supply adults for tests pupae were isolated each in a glass vial and after emergence females, or males, of the same age were put in a screen cage and provided with a sucrose solution. Thus virgin females and males of known age were available for experimentation.

GVM pheromone

At the beginning of this work the pure GVM pheromone (E,Z)7,9-dodecadienyl acetate was not available, but only dispensers made of rubber septa (Arthur H. Thomas Co.) impregnated each with 1 mg of this pheromone which were supplied by INRA France. At a later stage of the work pure pheromone was supplied by INRA and Chimada, Israel. Our standard bait was then made of rubber septa (Arthur H. Thomas or Maavit, Israel) each impregnated with hexane solution of 1-2

mg pheromone. The dispensers were allowed one day for evaporation of the hexane before being used. In preliminary tests we found no differences in biological activity between the two kinds of rubber septa and between the pheromones of the two sources.

EAG Recording

Chemicals: Ninety chemicals identical or structurally related to insect pheromones were used in the EAG study. They were supplied by the USDA laboratories in Beltsville, MD, and consisted mainly of mono- or diunsaturated aliphatic alcohols, aldehydes, and esters of 12, 14, and 16 carbon atoms. Their geometric purity was at least 95% and alcohol content was zero in all esters and aldehydes.

For electrophysiological study, each chemical was dissolved at various concentrations in n-hexane and 50 μ l of each solution were absorbed on a 1-cm² piece of filter paper. As soon as the solvent evaporated, the filter papers were stored separately in 4-ml screw-cap bottles kept at minus 20°C. until used for biological assay.

EAG Recording: The classical method of EAG recording (Schneider 1957, see also Boeckh et al. 1965) was employed, with the following modification: the whole insect was firmly fixed, a piece of absorbent cotton moistened with physiological solution was attached to the posterior end of the insect body, and the indifferent electrode was connected to the cotton. The recording electrode was in contact with the antennal tip. The antenna was stimulated by puffs of fresh filtered air (2 l/min) of 0.5 sec duration passing through a glass tube into a glass cartridge, 50 mm long, 7 mm ID, containing a 1-cm²

filter paper impregnated with the candidate chemical. The outlet of the cartridge was 4 cm from and facing the antenna. The cartridge was replaced for each chemical tested. Such a preparation remains viable for an entire work day.

EAG assays were carried out as follows: 3 males were subjected to stimulation of the whole list of chemicals at random sequence; each compound was tested at a concentration of 10 ug on filter paper. Chemicals which caused a significant EAG response were tested again 2 or 3 times. Time intervals between 2 subsequent stimuli were at least 2 min. There were differences in EAG amplitude of different males exposed to the same chemical but the relative effect of the various chemicals was similar for every male tested.

Field tests

All disruption tests were done in two vine growing areas - Gezer and Mikve-Israel. The vineyards in which tests were made as well as the surrounding vineyards were treated with insecticides by their owners according to infestation. Tests on mass trapping were done in small isolated vineyards situated several kms away from commercial vineyards. Insecticides were applied in these vineyards according to pest infestation.

Pheromone traps were made of waxed drinking cups smeared on the inside with glue (Stikem Special, Michel & Pelton Co. Ca.). Each trap was baited with either rubber septum impregnated with 1 or 2 mg of GVM pheromone or with 2-4 two day old virgin females caged in a small screen cage. Traps were hung from the top wire of the trellises at a height of 1.5 m (which is the canopy of the vines) and were left in

the vineyards during the test period. The pheromone loaded rubber septa were replaced with fresh septa once a month. Females were replaced with fresh females every 2-3 days. Trapped males were removed from the traps at time of male catch recording. Different kinds of dispensers impregnated with GVM pheromone or other chemicals were used as pheromone source in the disruption tests. These included 0.5 x 4.5 cm rubber strips each impregnated with 50 mg pheromone-like compound. Arthur H. Thomas (U.S.A.) rubber septa and Maavit (Israel) rubber septa impregnated with 1 mg or 2 mg GVM pheromone (with no difference in activity between the two kind of septa). The pheromone was applied to these dispensers as a solution in hexane. Ready made dispensers were supplied by Hercon (U.S.A.). These were 1" x 1" polymeric vinyl laminated units. At first each unit was impregnated with 6.15 mg pheromone with release rate of 0.1 mg pheromone a day at 25C. At a later stage we received such units absorbed with 40 mg per unit with release rate of 1 mg/unit/day. The distance between one dispenser to the other and the number of dispensers per replicate are described in the results section. In most cases however the distance between two dispensers was 3 m and in each replicate at least 3 adjacent vine rows were treated. (The distance between rows is 3 m in all vineyards). Pheromone traps were set in the midway between two dispensers in the center of the treated plot. The dispensers were set out on a triangle system so that if distance between dispensers along the row was, for example, 3 m, the distance between the trap to the two adjacent dispensers of the same row was 1.5 m while its distance to each of the closest dispensers set on the adjacent rows was 3 m. Three to four replicates of a plot consisted of one trap surrounded by

4 to 14 pheromone sources (dispensers) was used for each treatment. No pheromone sources were set around control traps. The distance between one plot to the other was at least 60 m.

Another way of releasing pheromone in the disruption tests was by stretching on a three-ply flax string of 1.5 mm diameter (a common binding string) impregnated with pheromone, along the upper wire of the trellises. The string was washed 3 times with hexane and dried before impregnating with a hexane solution of the pheromone. The flax string was used in the tests soon after the hexane evaporated. In each plot the string was laid along 6 m of three parallel vine rows and the trap posted in the midst of the inner row, or the string was laid on each second row and the trap was posted in the untreated inner row at the center of the plot.

In one case we used Accurel wettable powder impregnated with GVM pheromone - supplied by Anka, Germany - to disrupt male orientation to pheromone traps. Unfortunately the amount supplied was not sufficient for more than two tests.

Three isolated small vineyards were chosen for the mass trapping. Two of the vineyards, each about 9 dunam and 100 m apart were used for the mass trapping. The third, 1.5 dunam, situated 200 m away was not treated and served as control. The two treated vineyards were each divided into two plots, in one of these pheromone traps were placed in a 9 by 8 m grid outline (Treatment A). In the second plot of each vineyard the traps were placed in a 15 by 15 m grid system (Treatment B). Traps were left in the vineyard from the beginning of April to the end of July. During this period the rubber septa were replaced with fresh pheromone loaded septa three times (about each month).

Trapped males were removed from the traps and counted once a week. Similar traps each containing 2 virgin females were hung on both the treated and untreated plots at a density of one trap per 0.75 dunam. These traps served to compare male population density in the treated and untreated plots. The females were changed twice a week and counts of male catches were made. For evaluation of mating, vinegar traps were suspended in all plots at a density of one trap per 1.5 dunam. The vinegar bait was replaced twice a week at which time the trapped females were collected and examined under a microscope for the presence of spermatophores. Infestation counts were taken prior to harvest by checking randomly 200 to 300 clusters throughout each plot.

RESULTS AND DISCUSSION

Grape berry moth

Sex pheromone blends

The data from tests evaluating blends of the pheromone compounds are presented in Tables 1, 2 and 3. Footnotes to tables 1 and 2 show the number of laboratory reared male moths released in each test block and the number and percentage trapped. The least attractive traps were those charged with Z9-12:Ac alone or this compound plus very small amounts of Z11-14:Ac (Tables 1 and 2).

Additional tests were continued in 1983 to further confirm the 1982 results obtained on released laboratory-reared male GBM moths. A comparison was made of traps charged with rubber septa containing 9:1 blend of Z9-12:Ac + Z11-14:Ac and traps charged with production septa (Zoecon Crop., Palo Alto, CA) containing Z9-12:Ac. This comparison was made against wild male GBM moths. At the end of three weeks of trapping the blend attracted an average of 61 males per trap, whereas with Z9-12:Ac alone as the attractant only 10, on average, were captured per trap.

The 4 female GBM sex pheromone blends evaluated in 1984 are listed in Table 3 along with the number of wild male moths attracted with the various blends. The blend of Z9-12:Ac + Z11-14:Ac attracted the greatest number of male moths. These data support the records from earlier tests. The performance of the above blend was not improved by the addition of other acetate and alcohol compounds.

Longevity of sex pheromone treatments

The length of time and the level of disruption of male GBM to pheromone charged traps was determined when only a single treatment

was applied. The releasers were rubber septa each containing 9:1 blend of Z9-12:Ac + Z11-14:Ac and one septum was used per vine. The trial to evaluate the one treatment was carried on for a period of nine weeks. During this time 23 male moths were captured in the treated plot and 818 males in the check, a difference of 97% in the number trapped (Table 4). Male disruption at weekly intervals ranged from 93 to 100% per week. At the end of the ninth week male disruption amounts to about 95%. A single pheromone treatment giving male disruption to traps for a similar length of time was reported when hollow fibers were used as releasers (Taschenberg & Roelofs, 1977).

A comparison of the number of male moths attracted to traps charged with the synthetic pheromone and those charged with live female GBM (five 2-day old virgin moths) show the former to be more attractive than the latter (Table 4).

Traps charged with synthetic pheromone being significantly more attractive to male than live females has been reported for the potato tuber worm moth, Phthorimaea aperculella (Raman, 1984) and the cutworm Feltia jaculifera (Steck et al, 1986). Of interest in this connection is the attractancy of traps baited with synthetic pheromone and live female moths of the noctuid speices, Euxoa messoria (Palaniswamy et al, 1984). These workers reported that traps charged with the above sources of attractancy showed no significant difference in catches of male moths.

A single application of laminated plastic flakes, using one/vine and each containing 4.37 mg of synthetic pheromone was evaluated for male GBM disruption. In each plot, 326 laboratory-reared male moths,

a rather small number, were released over a period of 3 weeks. During the 1st week after treating the disruption was rather low, 63% (Table 5). The effect of the treatment continued to decline rather rapidly, amounting to only 25 and 23% disruption in the second and third weeks, respectively. The results suggest that the rate of pheromone application 4.73 mg per flake per vine was insufficient for producing a high level and continued male disruption.

Disruption and control experiments

During 1982 two potential releasers for the female GBM sex pheromone were tested in commercial vineyards. One was Celcon polyoxymethylene hollow fibers and the other was laminated plastic flakes. In the vineyards wherein the hollow fiber releaser trial was conducted the GBM damage to berries at harvest was light only 8.3% of the berries were injured at harvest (Table 6 and 7). This light population should have been ideal for the test. However, against this low infestation the hollow fiber releasers in a schedule of five well-timed applications gave only 88% disruption in orientation to monitoring traps. The control efficiency of the hollow fiber schedule was 74% which is commercially unacceptable.

Four lots of 50 fibers (8 ml opening) each were weathered in grapevines and measurements were made on the decrease in height of the GBM pheromone (88.2%, Z9-12:Ac, 1.8%, Z11-14:Ac and 10%, hexane) column in each fiber. These observations were made at weekly intervals for a period of 16 weeks.

During the first three weeks there was little change in the amount of pheromone released; ca 88% of the fibers released no more

than 2 mm of the pheromone. Releases by each lot of hollow fibers appeared to be rather uniform.

In the trial screening the laminated plastic flakes formulation GBM injury to berries in the checked plot was heavy, 18.8% of the berries showing injury (Tables 6 and 7). The pheromone-plastic flake releaser formulation in a schedule of five applications was ineffective, giving only 49% control efficiency. This program gave 97% disruption of male orientation to traps. This degree of male disruption was not reflected in the records on GBM control.

The formulation of the pheromone blend; 91%, Z9-12:Ac and 9%, Z11-14:Ac at the rate of 100 mg per rubber septa, using one septum per vine per application was evaluated in a five-treatment program in 1983 (Table 6 and 7). It gave 100% disruption of male moths to pheromone baited traps. At harvest 16.4% of the berries in the check were injured whereas in the treated plot berry injury amounted to 8.4%. With the program of five treatments there was ca 50% control efficiency.

Again, in 1983, trap catches of male moths in the pheromone treated plot and in the checked plot provided evidence of a high degree of disruption. Therefore, the fruit should have been relatively free of GBM injury at harvest but this was not the case.

The pheromone G Type Releaser formulation was used in an abbreviated schedule of only three applications. This was two less applications than was applied in earlier tests with other releasers in 1982 and 1983. The amount of pheromone blend, 180 mg, 2 releasers applied per vine per application was a higher rate than had been employed in other years. From 6/13 when the first treatment of a

three-treatment GBM pheromone control program was made and 9/21, a period of 100 days, no male moths were captured in traps in the treated plot. In the untreated check during the same period 211 male moths were trapped.

Harvest counts were made on clusters for the purpose of estimating the amount of GBM injury (Table 7). In the check there was an average of 7.2 (22.7%) damaged berries per cluster. On clusters from the treated there was an average of one (less than 3%) injured berry per cluster. The program gave a control efficiency of 88%.

A pheromone release rate study was carried out by weathering ten Type G Tube Releasers. These releasers were not exposed to direct sunlight and were supported 1.5 m above ground level on a trellis post in a producing vineyard. During the 98 day weathering period the amount of pheromone blend released was recorded at weekly intervals.

From the data in Table 8 it is seen that the tube releasers were releasing the pheromone blend at rate of 0.035 mg/h for the first 12 weeks of testing. Each treatment of 1200 tubes/0.4 ha would give a release rate of 10/mg/h/ha. In tests prior to 1984 only 1-5 mg/h/ha release rates of pheromone were used.

During the past eight years encouraging results were obtained on wild moth disruption to traps with various pheromone formulations. Disruption was often the order of 90% and above. However, the same treatments failed to be effective in controlling the GBM. Control was usually less than 70%, which is unsatisfactory commercially (Taschenberg and Roelofs, 1976 and 1977 and Taschenberg and Roelofs unpublished data). The pheromone-G Type Releaser formulation applied so the release rate was 101 mg/h/ha/application gave a high percentage

of disruption as well as a high percentage reduction of berry injury at harvest. Field tests are being continued with this releaser and the pheromone blend Z9-12:Ac + Z11-14:Ac, 9:1 respectively.

Grape vine moth

The effect of Pheromone-Like Compounds on sexual attraction

The use of chemicals other than the natural pheromone to disrupt intersexual communication has been tried in some insect pests (Z)9-Tetradecenyl format, for example, has been found effective in disruption tests with Heliothis virescens (Mitchell et al., 1975). This compound is available commercially and it is much less expensive than the synthetic pheromones of H. virescens. In the codling moth, an acetate derivative of the sex pheromone proved to be an effective disruptant when applied in the orchard (Hathaway et al., 1979). At an early stage of the present project we checked the possibility of using other insect pheromones or similar compounds, to disrupt sexual attraction in GVM. Although the GVM sex pheromones had been already identified at that stage as (E,Z)7,9-dodecadienyl acetate (Roelofs et al., 1973) it was not available commercially. It was also expected that synthesis of this compound will be more costly than production of pheromone analogues of a more simple formula, in fact some of the compounds tested here were available in the market for a reasonable price.

Among 90 compounds available in our laboratory from previous tests (Gothilf et al 1978 Table 1), we selected the more promising ones by recording the electroantennogram response of male GVM to each one of these compounds. Nine compounds were found more active than the others, generating an antennal electrical response of 2.5 to 5.0

mv. These are listed in Table 9. All other compounds caused an electrical response of 0 to 2.4 mv. Unfortunately the GVM pheromone was still not available at that stage so it could not be included in the EAG tests. The three most stimulating compounds which are mentioned in Table 9, were further tested in the field. The quantities of the other chemicals listed in this table were not enough for field tests. Of the compounds which were less active (EAG response of 0 to 2.4) we chose three compounds for comparison in the field tests. These and the corresponding EAG they evoked were (Z)-7 dodecenyl acetate - 2.3 mv, (Z) 9-tetradecenyl acetate - 1.9 mv and (Z) 9-tetradecenyl format - 0.6 mv.

When each of the three electrophysiologically most active compounds were placed in commercial GVM pheromone traps which contained 1 mg GVM pheromone impregnated on rubber septum, less males were caught in the traps as compared to the control traps which contained only GVM pheromone. The inhibition in trap catches ranged from 70.0% to 97.6% (Table 10). A much smaller inhibitory effect resulted from the addition of (Z)9-tetradecenyl format to traps. As shown above this compound had only a small stimulatory effect in the EAG tests.

The disruption effect of the pheromone analogues was tested. Chemicals absorbed on dispensers made of rubber strips were placed on 4 sides of a pheromone trap at a distance of 3 meters from the trap. One dispenser absorbed with 50 mg of the chemical on each side. The disruption effect of GVM pheromone was also tested. Commercial rubber septa each impregnated with 1 mg pheromone (the only GVM pheromone formulation available at that time) were placed as above, one

dispenser on each side of the trap. The results of this test showed that all the chemicals tested significantly reduced the number of male catch with not much difference in their effect. However, the effect of all these chemicals was inferior to that of GVM pheromone, although applied in quantities 50 times larger than the pheromone.

Chemicals which were considered promising according to the EAG test were confirmed as inhibitors when applied inside pheromone traps (Table 10). On the other hand, when it came to disruption tests where chemicals were applied at a distance from the traps, there was no difference between these chemicals and those which were less active in the EAG test. All caused some reduction in male catch when applied in relatively high concentrations, but were less effective than rubber dispensers impregnated with GVM pheromone at much smaller concentration (Table 11). It is possible that EAG response to stimulation by chemicals other than the true pheromone was related to a repellency effect of these chemicals on the insect. Rothschild (1974) has shown that such chemical repellents may be effective inhibitors when applied very close to the bait, but have no disruption effect when applied away from the bait. Roehrich (1977) found that the EE isomer of the GVM pheromone was less effective in trapping GVM males.

Disruption of intersexual communication by releasing the pheromone from different dispensers.

A. Pheromone released from rubber septa.

Rubber septa impregnated each with 1 mg pheromone were the first products of GVM pheromone commercially available (supplied by INRA,

France). Originally these septa were designed for use as a bait in pheromone traps. We first tested them for their disruptive effect on male orientation into pheromone traps as described before (Table 11) and into traps baited with live virgin females as follows: Rubber dispensers were suspended at various distances around the baited traps. Three consecutive tests were done in the same vineyard, each test lasting about 2 weeks. In all three tests the presence of the rubber dispensers around the traps caused a significant reduction in male catch compared to male catch in traps with no dispensers (Table 12). Surprisingly the changes in distances between dispensers had but a slight effect on the number of male catches. A distance of 3m between dispensers which is equivalent to 111 mg pheromone/dunam (Tests 1,2,3) or even a distance of 1 m (Test 2) which is equivalent to 333 mg/dunam did not differ much in their effect from that of the more widely spaced dispensers, i.e. 9 m, whose equivalent amount of pheromone per dunam was as low as 12 mg/dunam.

B. Pheromone released from Herculite polymeric vinyl laminates.

Male catch in traps loaded with Herculite dispensers.

Before starting disruption tests with the Herculite dispensers it seemed desirable to check their ability to stimulate GVM males. This was accomplished by testing different amounts of these dispensers in traps and recording periodically male catches. In the first-test two different loadings of 1/8 dispenser and 2 dispensers per trap were compared to a standard rubber septum impregnated with 2 mg of GVM pheromone. Less males were caught in the traps loaded with Herculite dispensers than in traps loaded with the standard rubber dispenser

(Table 13). In another test where 1/4, 1 and 4 Herculite dispensers were compared to the standard dispenser it was shown that the 1/4 dispenser was more attractive than 1 and 4 dispensers and was comparable to the rubber dispenser (Table 14). This result confirmed the biological activity of the Herculite dispensers which were used thereafter in disruption tests. The above result also gives an idea of the optimal pheromone release rate for trapping males which is about 0.025 mg/day (the release rate of 1/4 unit of 1 x 1" Herculite laminated plastic).

Disruption Tests with Herculite Dispensers.

Five disruption tests were done with Herculite dispensers during the 1982 season. The number of dispensers ranged from 1/2 to 8 dispensers at each source point (4 source points around a pheromone trap). The effect of these dispensers on male catch in pheromone traps was recorded every 1 to 3 days and was compared to control traps with no dispensers around them. The results of these tests are summarized in Table 15. Numbers shown are total catches during the testing period in the 3 replicated traps of each treatment. The results show that the presence of Herculite dispensers caused a reduction in male catch but in most treatments this reduction is considered too small for practical mating disruption. It is not clear why the increase in the number of dispensers to 8 per a source point, which is equivalent to a release rate of 44 mg pheromone/dunam/day, was not followed by a greater reduction in male catches.

In the 1983 season we used Herculite laminates of higher release rate. It was shown that when units were set every 3 meters there was

no advantage in using more than one unit per release point (Table 16). Apparently at such a distance the concentration could be reduced to even less than 1 unit per release point without a reduction in disruption efficiency. However, a concentration as low as 1/10 unit per point decreased disruption efficiency as seen in the first test. In the tests described in Table 16 a reduction of over 90% in male catch was noticed only in a population of low density, which is less than 1 male catch per control trap/day.

Later in the season we tried closer set up of release units of smaller size. Releasers were hung at a distance of 0.5 m or 0.25 m along the vine row and were compared to a setting of one unit every 3 m (Table 17). In most of these tests the disruption effect was smaller than the effects recorded in the previous tests described in Table 16. The setup of closely spaced smaller release units though significantly increased the amount of pheromone applied per dunam did not seem to have any significant advantage compared to the setting of one unit every 3 meters. Only in the last two tests made in October and November did the disruption effect of 1/10 unit per 0.5 m or 0.25 m reach over 90%. It is possible however that a setting of 1 unit per 3 meters would have given the same effect if tried at that time.

The results obtained with Herculite polymeric vinyl dispensers (Tables 15,16 and 17) showed that it is difficult to inhibit complete male GVM trapping by the above method of pheromone release. In some tests the release rate of these dispensers per field area unit was relatively high (e.g. 444 mg/day/dunam in Test 5, Table 16), hence the low disruption effect recorded in these tests is apparently not a result of insufficient release of pheromone. There are however some

conclusions that can be drawn from the results. First, higher rate of inhibition was usually achieved in low populations. This is obvious in most tests described in Table 16. Second, it seems that very close setting of dispensers improve the disruption effect. This is seen in some of the tests described in Table 17. Such a conclusion, however, is contradictory to the results obtained in the first disruption test described in Table 12, where no difference was found between close and wide setting of the rubber dispensers. It should be borne in mind, however, that the release rate of a rubber septum is the optimal rate for male attraction and perhaps even at the wider spacing they attract enough males and can compete with the pheromone traps. We, therefore assume, according to the results with the Herculite and rubber dispensers, that male GVM are not easily adapted to the pheromone odorant even at the higher concentration employed in this work, and apparently they may even be repelled from high concentrations around such pheromone sources. If this is really how GVM males behave the only way to compete with females or pheromone traps is to set in the field other pheromone sources with optimal release rate attractive to the males, preferably at short distances.

D. Disruption effect of Accurel powder spray.

This experimental synthetic powder impregnated with GVM pheromone produced by Enka was supplied by Dr. A. Shani of Ben Gurion University. It is a wettable powder which contained 300 mg GVM pheromone per 1 g powder. A complete inhibition in male catch was obtained one or two days following the spray and then it diminished gradually (Tables 18 and 19).

The results of the tests with the Accurel spray (Tables 18 and 19) indicate that better inhibition can be achieved with spray formulation. Unfortunately the activity of the Accurel spray lasted 1-2 days. No other spray formulations of GVM pheromone is available at present. A spray formulation of microencapsulated pheromone has been prepared by some manufacturers and was tried with a few insects, but their activity lasted only a short time because the emission rate of the pheromone from such preparations is high soon after application, and drops sharply after a short time (Bierl-Leonhardt, 1982).

E. Pheromone released from flax string.

All tests heretofor have shown that placing pheromone dispensers around pheromone or virgin female traps could not completely inhibit trapping of the males. However, the results of some tests together with the result of the spraying of Accurel powder indicated that dense spacing of the pheromone source might be important for efficient disruption. Since no spraying or dusting formulation of GVM pheromone was available (except the experimental Accurel powder) we tried in the 1984 season the effect of pheromone released from a three ply flax string stretched along the vine rows. The first test showed that this flax string absorbed with 30 mg pheromone/m (= 10 g/dunam) inhibits completely male trapping during 7 days and was still very effective until the termination of the test (Table 20). On the other hand flax string absorbed with 3 mg pheromone/m was not effective enough in inhibiting male trapping. It was then found of interest to know if loads lower than 30 mg/m would be also effective. Three weeks later,

on June 1, a second test was started at another location. A load of 30 mg/m was compared to a load of 15 mg/m. Unfortunately the moth population at that location was too low during the 77 days of the test to allow for meaningful results (Table 21). If any conclusion can be drawn from this experiment it is that the disruption effect of the pheromone loaded flax string did not last long since a trapped male was recorded at each of the two treatments on day 19.

The vineyard in which the first test was done (Table 20) seemed to be more suitable for further experiments because of its higher population of GVM. Three consecutive tests with flax string as pheromone dispenser were run in that plot and the results are described in Tables 22, 23 and 24. In one of these tests the flax string was impregnated with 10 mg pheromone per meter which decreased its disruption effect compared to a string impregnated with 30 mg per meter (Table 22). The effect of both kind of flex string lasted about one month but the effect of even the higher load was smaller than that found in the previous test (Table 20) made in this plot. Apparently the decrease in disruption effect was a result of the increase in GVM population. This may also explain why in a following test (Table 23) the inhibitory effect of the pheromone released from the flax string was usually low. Here and in the last test (Table 24) we tried to place the flax string every second row but it proved to be much less effective. The last test was done at the end of the season when the population diminished greatly. The disruptive inhibitory effect of flax string, at a load of 30 mg pheromone/m and with regular placing on every row, reached 100%.

We chose to use flax string as dispenser because it could be stretched continuously along the vine row and it easily absorbs the pheromone and also because its degradable character, which is an important attribute in case it would be used commercially. Stretching such a string absorbed with 30 mg pheromone per meter along the vine rows was usually very effective in inhibiting male catch in the pheromone traps during the first few days of the tests and sometimes quite effective for a month or more (Tables 20 to 24). The disruption effect of the flax string was more pronounced in low pest populations as found also in the previous tests with Herculite and rubber dispensers. It can be concluded that neither of the dispensers used at various spacing and with different concentration of pheromone, proved to completely disrupt male orientation to pheromone or female traps at all population levels and for a reasonable period of time. It follows that chances to control GVM by using its pheromone are small at present and more behavioral and chemical research is needed to understand the reasons for the difficulties in confusing male GVM by the use of pheromones. One possible reason for this is that the natural pheromone may contain more than the one compound which is presently known and that this, or these, additional compounds affect the sexual behaviour of the males. Combining such compounds in disruption tests might improve the results. Many recent research works with other insects have shown that the natural pheromone of most insects is a blend of a few components and that even secondary components of lower concentration might have significant stimulatory effect along the sequence of male behavioral reaction to the pheromone. (e.g. Baker et al. 1984, Steck et al. 1980 and 1982.)

The possibility that the pheromone of GVM of our area contains more than one component may also explain the difference between our results and those of Roerich and his colleagues in Europe (Roerich et al. 1977, 1979). In their experiments a disruption effect was demonstrated in a vineyard treated with as little as 2 g pheromone per dunam with a release rate of 38 mg/dunam/day (Roerich et al. 1977). It should however be mentioned that even in the European tests the disruption effect was not absolute and infestation by the pest could not be completely prevented.

Control of GVM by mass trapping of males.

The network of pheromone traps spaced 9x8 m (Treatment A) captured altogether less males per trap than the traps posted 15 m apart (B), however on per area basis the more densely spaced traps (A) captured 115 males/dunam compared to 91 males/dunam in treatment B (Table 25). It is possible that closer spacing of traps would increase the number of males trapped per area. Live female traps captured much less males in the treated plots (Treatment A and B) than in the untreated plot (C), proving that the pheromone traps significantly reduced the number of males (Table 25).

As shown in Table 26 the number of females trapped in the lure cans in the treated plots (A,B) was smaller than in the untreated plot (C). However, the incidence of mating, although smaller among females in treated plots, was nevertheless high, exceeding 50%.

Grape infestation counts showed the percent of clusters injured by the GVM to be 6 and 9.3% in treatment A and B respectively as compared to 20.6% in the untreated plot (Table 26). The routine chemical

control of GVM in Israel requires 4-5 treatments during a season. In our experiment there was a need for 2 insecticide treatments in plots under treatment A and B. The control plot (C) was sprayed 3 times and would have required additional treatments but was not sprayed in order not to blur the data of a control plot.

The results of the mass trapping experiment suggest that mass trapping of male GVM can cause a reduction in the moth population, reduce damage to the fruits and can save about two to three insecticide treatments in a season. Although the female population was probably reduced following mass trapping of males, more than half of the females were mated. The relatively high rate of mating in the treated plots may be explained by the presence of surviving males which were not trapped and were in number enough to copulate with the relatively small number of females in these plots. Alternatively, the high rate of mating can be attributed to immigration of mated females from neighboring homeyard vines. Roehrich et al. (1977) reported high rate of mating in female GVM in plots where mating disruption was tried and concluded that this was the result of displacement of mated females from adjoining vineyards to the treated areas. Results of the mass trapping tests could possibly be improved by using a larger number of traps per area unit. However, even with the present density, the amount of labor involved in trap handling makes the economics of mass trapping of this moth, as compared to conventional control , questionable.

Honeydew moth

Identification of the sex pheromone of this moth has not been completed (Bjostad et al., 1981). However, chemical analysis of the pheromone gland extract has shown that it contains 16 and 18 carbon monounsaturated aldehydes and a mixture of four isomers of these aldehydes was found to be an effective lure for the males (Bjostad et al., 1981).

Originally it was planned to study the possibility of mating disruption in this moth by permeation of the vineyard atmosphere with the sex attractant odor. However, only partial work was actually done mainly because we were unable to obtain sufficient quantities of the attractive mixture for extensive field studies.

In spite of the increasing importance of the honeydew moth as vine and other fruit pest no data is available on the phenology of this moth. Therefore, in 1982, we recorded the occurrence of adults throughout the year by using pheromone traps. The trapping records showed that significant adult activity starts as late as May and that population density reaches high peaks late in the summer - September through November (Table 27). Considering this result, it seems that pheromonal control of this moth should be tried in April when the population is about to build up.

Only one experiment on pheromonal control of the honeydew moth was done, starting on December 20, 1984 (Table 28). In spite of the mild weather which occurred in that season, the population level was already too low to get meaningful results. However it is possible to speculate, according to the data of this test, that male orientation to females can be disrupted when high doses of sex attractant are applied in the vineyard.

DESCRIPTION OF COOPERATION

The male disruption and control studies on grape berry moth were carried on with sex attractants by E.F. Taschenberg. Similar studies were conducted on the grape vine moth and honeydew moth in Israel by S. Gothilf and E. Gurevitz. These workers cooperating investigators, traveled to USA. The purpose was to discuss problems arising in connection with research on pheromone control technique with the principal investigator and D. W.L. Roelofs. The latter and his staff identified the GVM and HDM pheromones. When the application was made for the grant Dr. Roelofs had agreed to make available time for consultation with all parties either by direct communication or by mail. Because of circumstances beyond his control the principal investigator was unable to make the trip to Israel. In spite of this studies on GBM pheromone was continued in 1984.

The attached final report on pheromone research aimed at controlling the GBM was prepared by the principal investigator. That of the GVM was prepared by the cooperating investigators.

MAIN ACHIEVEMENTS OF THE RESEARCH

During this investigation a component of the GBM pheromone complex, Z11-14:Ac, was isolated and identified. When blended, one part, with nine parts of Z9-12:Ac the performance of monitoring traps was improved. As a result traps baited with the blend provides more accurate records on both male moth activity and size of male moth population. This information can be used to more accurately time treatments for GBM control and also reduce the amount of insecticide applied annually in vineyards.

The results obtained on male moth disruption and GBM control at harvest with the pheromone-G Type Releaser formulation in a schedule of three treatments were very encouraging. However the formulation cannot be recommended for commercial use at this time. It appears to be promising enough to warrant further field testing. The objectives would be to evaluate reduced rates of pheromone per treatment and schedules of fewer treatments.

Although the present study on pheromonal control of the GVM did not reach an applicative stage much information has been accumulated on which further research should be based. The present results suggest that pheromone-like compounds should not be considered in mating disruption tests since these chemicals, even as effective stimulants of male olfactory sense cells, fail to interfere with male orientation to pheromone source in the field. Other results show that polyvinyl laminated dispenser, even if loaded with large amounts of GVM pheromone, were not efficient disruptant at high dense population. The disruptive effect could be improved by close setting of the dispensers or by release of the pheromone from a flax string

stretched along the vine row, or by application of the pheromone as spray formulation. It appears that for optimal disruption the pheromone release sources should be closely spaced as in spray droplets and the release of each source point should be at optimal rate competitive to that of a calling female. It is suggested that further research should be focused on development of microencapsulated formulation.

As this work shows, saving in insecticidal application is possible following mass trapping of males GVM. It is possible that this technique might be more effective if practiced on larger areas. However, an easier and less expensive way of handling traps should be found first.

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Table 1. Data from the experiment to evaluate the attractiveness of ♀ GBM sex pheromone blends, Z9-12:Ac + Z11-14:Ac, 1982.

Z9-12:Ac, 30 + Z11-14:Ac %	Mean No. ♂♂ /trap ^{2/}
0	17
1	18
3	23
6	48
9	42
12	29
15	36

^{1/} Rubber septa used as dispensers.

^{2/} 2305 ♂♂ moths released and 857 (37.2%) captured in traps during test period 7/12 to 8/12, 1982.

Table 2. Data from the experiment to continue the evaluation of the ♀ GBM sex pheromone blends Z9-12:Ac + Z11-14:Ac, 1982.

Z9-12:Ac, 30 + Z11-14:Ac ^{1/} % μ		Mean No. ♂♂/trap ^{2/}
6	100	34
9	30	16
9	100	46
9	300	55
15	30	24
15	100	41
15	300	30

^{1/} Rubber septa used as dispensers.

^{2/} 3406 ♂♂ moths released and 1233 (36.2%) captured in traps during test period 8/16 to 9/17, 1982.

Table 3. Number of $\sigma\sigma$ GBM attracted to sticky traps charge with various blends of the $\varnothing$ GBM pheromone fractions, 1984.

	GBM $\varnothing\varnothing$ sex pheromone fractions 100 ug of mixture/septum						No. $\sigma\sigma$ GBM ^a /trapped	
	Test 1		Test 2		Test 1 & 2			
	Z9-12:0Ac 100%	Z11-14:0Ac 7%	11-12:0A 1%	12:0Ac 9%	14:0Ac 4.5%	Z9-12:0H 1.5%	No. %	No. %
0	--	--	--	--	--	--	0 --	0 --
1	+	+					182 41	131 44
2	+	+	+				156 31	83 28
3	+	+	+	+			84 20	65 22
4	+	+	+	+	+	+	45 8	18 6.1
							467	297
								764

a/Wild $\sigma\sigma$

b/Percentage of total catch.

Table 4. Results from a test to determine the longevity and performance of a single pheromone treatment applied for the purpose of disruption of $\sigma\sigma$ moth orientation to monitoring traps, 1983.

Time (wks) & dates ^{d/}	No. $\sigma\sigma$ released ^{f/} plot/wk	No. GBM $\sigma\sigma$ ^{a/} captured in monitoring traps ^{b/} /wk			
		Source of sex pheromone in traps			
		5 2-day-old virgin $\sigma\sigma$ 10 traps ^{a/} /plot ^{d/}	100 μ /trap ^{d/}	Synthetic pheromone blend 100 μ /rubber septa 6 traps ^{a/} /plot ^{e/}	
Pheromone treated plot ^{h/}	check plot	Pheromone treated plot ^{h/}	check plot		
1st	237	0	4	3	218
7/15-21	72	0	1	0	76
2nd	240	0	1	2	49
7/22-28	155	0	4	1	84
3rd	130	0	1	0	48
7/29-8/4	140	0	2	4	78
4th	130	1	0	11	147
8/5-11	55	1	2	0	79
5th	57	0	2	2	39
8/12-18					
6th					
8/19-25					
7th					
8/26-9/1					
8th					
9/2-8					
9th					
9/9-15					

^{a/} Laboratory reared $\sigma\sigma$ moths released.

^{b/} Zuecon Pherocon[®] 1G trap.

^{c/} Laboratory reared $\sigma\sigma$ moths.

^{d/} Traps distributed in this order in a 16 row wide plot, rows 2, 4, 6, 11, 13 & 15.

^{e/} Six traps in each plot; 3 in each of these rows 8 & 9.

^{f/} Same number of $\sigma\sigma$ moths released in rows 7 & 10 of the 16 row wide treated and check plots.

^{g/} Experiment initiated on 7/14.

^{h/} 100 μ pheromone blend (9:1, Z9-12:Ac + Z11-14:Ac respectively).

Table 5. Results from a test to evaluate a single synthetic sex pheromone treatment using Herculite Laminated plastic flakes as the pheromone releaser, 1983.

Time (wks) & dates ^{g/}	No. $\sigma\sigma$ released ^{f/} per plot per week	No. GBM $\sigma\sigma$ ^{a/} captured in sticky trap ^{b/} /wk Source of sex pheromone in monitoring trap			
		5 2-day-old virgin $\sigma\sigma$ ^{c/} 10 traps ^{a/} /plot ^{d/}		Syn. phero. blend 100 μ /rubber septum 6 traps ^{a/} /plot ^{e/}	
		Pheromone treated plot	Check plot	Pheromone treated plot	Check plot
1st 8/23-8/29	160	0	0	13	35
2nd 8/30-9/5	85	2	2	12	16
3rd 9/6-9/12	81	0	2	34	44
	326	2	4	59	95

^{a/} Laboratory reared $\sigma\sigma$ moths released.

^{b/} Zoecon, Pherocon[®] 1C traps.

^{c/} Laboratory reared $\sigma\sigma$ moths.

^{d/} Traps distributed in this order in a 16 row wide plot, rows 2, 4, 6, 11, 13 & 15.

^{e/} Six traps in each plot; 3 in each of these rows, 8 & 9.

^{f/} The same number of $\sigma\sigma$ moth released made in rows 7 & 10 of the 16 row wide treated and check plots.

^{g/} Experiment initiated on 8/23

^{h/} 4.37 mg. of pheromone blend (9:1 Z9-12:Ac + Z11-14:Ac).

Table 6. Per cent disruption of σ orientation to pheromone charged monitoring traps in plots treated with a schedule of from 3 to 5 applications of synthetic $\varnothing$ sex pheromone. 1982, 1983 and 1984.

Year	Pheromone ^{1/} releaser & No. applied/vine/ application	Dates treatments applied No. treatments					No. $\sigma\sigma$ trapped	% σ disrup- tion
		1	2	3	4	5		
1982	Hollow fibers (10/strip); 1 Check	5/24	6/18	7/30	8/12	8/27	7 60	88
1982	Polymeric vinyl laminates (flakes); 1 Check	5/28	6/22	7/29	8/13	8/25	7 214	97
1983	Rubber septa; 1 Check	5/23	6/17	7/12	8/6	8/30	0 237	100
1984	Polyethylene tube: 2 Check	6/13	7/18	8/21			0 211	100

^{1/} The pheromone and pheromone blends given in the text.

Table 7. Performance of mating disruption as method of GBM control

1982, 1983 and 1984.

<u>Year</u>	<u>Pheromone^{1/} releaser & No. applied /vine/application</u>	<u>No. appl.</u>	<u>No. Clusters examined</u>	<u>% GBM</u>	
				<u>injured berries</u>	<u>control efficiency</u>
1982	Hollow fibers	5	600	2.1	74
	(10/strip); 1 Check	0	200	8.1	
1982	Polymeric vinyl	5	800	9.6	49
	laminates (flakes); 1 Check	0	300	18.8	
1983	Rubber septa, 1	5	1800	8.4	48
	Check	0	1200	16.4	
1984	Polyethylene	3	800	2.8	88
	tube; 2 Check	0	800	22.6	

^{1/}

The pheromone and pheromone blends given in text.

Table 8. Results from a release rate studies on ♀ GBM Sex pheromone
(9:1 Z9-12:Ac + Z11-14:Ac blend) using the G Type tube
releaser. 1984.

<u>Date</u>	<u>Release time week</u>	<u>Wt. Mg Pheromone released/tube (ave)^{1/}</u>
6/15		
22	1st	12.5
29	2nd	5.8
7/6	3rd	5.8
13	4th	8.3
20	5th	9.6
27	6th	6.0
8/3	7th	3.0
10	8th	7.5
17	9th	1.5
24	10th	5.0
31	11th	3.5
9/7	12th	2.0
14	13th	0.0
21	14th	0.0

^{1/} Average for 10 G Type Tube releasers.

Table 9. Grape vine moth male electroantennogram response to pheromone analogues

Compound	Antennal response mv
(E)7-Dodecenyl acetate	5.0
7-Dodecynol acetate	5.0
(Z,E) 9,11-Tetradecadienyl acetate	3.3
(E)9-Dodecenyl acetate	3.3
9-Dodecenyl acetate	3.1
(Z)8-Dodecenyl acetate	3.1
(E)10-Dodecenyl acetate	2.9
(Z)9-Dodecenyl acetate	2.9
(E,E)8,11-Dodecadienyl acetate	2.5
Control (pure air)	0

Table 10. The inhibitory effect of pheromone analogues applied in GVM
pheromone trap, on male catch

Compound added ⁽¹⁾ to GVM pheromone trap	Average number of males per trap ⁽²⁾	Per cent inhibition
(E) 7-Dodecenylacetate	17.2	79.8
7-Dodecenyl acetate	25.5	70.0
(Z,E) 9,11-Tetradecadienyl acetate	2.0	97.6
(Z)9-Tetradecenyl formate	65.7	22.7
None	85.0	

1) 1 mg absorbed in rubber septum per trap

2) Average of 3 traps during 18 days

Table 11. Disruption effect of GVM pheromone and other insect
pheromone and alike compounds on GVM male trapping

Chemical placed around trap ⁽¹⁾	Male catch ⁽²⁾	% inhibition
GVM phermone	0	100.0
(E)7-Dodecenyl acetate	3	92.7
7-Dodecenyl acetate	3	92.7
(Z,E)9,11-Tetradecadienyl acetate	2	95.1
(Z)7-Dodecenyl acetate	4	90.2
(Z)9-Tetradecenyl acetate	5	87.8
None	41	

(1) Four dispensers at 4 sides 3m away from a central trap.

1 mg GVM pheromon per dispenser made of rubber septum
and 50 mg of each of the other chemicals per dispenser
made of 0.5x4.5 cm rubber strip.

(2) Total of 3 traps during 25 days

Table 12. Effect of distances between pheromone dispensers on male catch in virgin females traps

Test	Distance between dispensers ⁽¹⁾ m	Pheromone per dunam ⁽²⁾ mg	Male catch ⁽³⁾	% inhibition
1				
May 15-	3 ⁽⁴⁾	111	10	96.2
June 3	6 ⁽⁵⁾	28	17	93.6
	9 ⁽⁶⁾	12	44	83.5
	Control	0	266	
2				
June 9 -	1 ⁽⁴⁾	333	3	97.2
July 2	3 ⁽⁴⁾	111	10	90.7
	9 ⁽⁶⁾	12	8	92.5
	Control	0	107	
3				
July 11-	3 ⁽⁴⁾	111	51	85.8
July 28	6 ⁽⁴⁾	56	70	80.6
	9 ⁽⁴⁾	37	92	74.4
	Control	0	360	

(1) Dispensers made of rubber septum impregnated with
1 mg pheromone.

(2) 1 dunam = 1/10 hectare

(3) Average of 3 replications

(4) Dispensers applied on every vine row (distance between
rows is always 3m)

(5) Every second row

(6) Every third row

Table 13. Male catch in traps loaded with Herculite laminated dispensers⁽¹⁾ and with rubber dispensers⁽²⁾ impregnated with grape vine moth pheromone

Days since beginning of the test	Number of males caught in 3 traps loaded with		
	1/8 Herculite dispenser	2 Herculite dispensers	Rubber dispenser
3	3	8	9
6	2	8	11
11	4	13	18
17	4	5	12
22	1	1	4
Total	14	35	54

(1) Each dispenser contains 6.15 mg of the pheromone.

Release rate 0.1 mg/dispenser/day.

(2) Each dispenser impregnated with 2 mg pheromone.

Table 14. Male catch in traps loaded with Herculite laminated
dispensers and with rubber dispensers impregnated with GVM
pheromone⁽¹⁾

Days since beginning of test	Number of males caught in 3 traps loaded with			
	1/4 Herculite dispenser	1 Herculite dispenser	4 Herculite dispensers	Rubber dispenser
1	12	8	3	15
4	30	21	5	23
6	28	14	6	26
9	13	6	3	13
13	20	11	8	30
18	14	9	10	7
Total	117	69	35	114

(1) Details of dispensers is given in Table 13.

Table 15. Effect of pheromone released from Herculite laminated dispensers on GVM male catches in pheromone traps

Test No.	Duration (days)	No. of Herculite dispensers in each source point ⁽¹⁾	No. of males/ trap ⁽²⁾	% inhibition
1	37	0	25	
		1/2	2	92
		2	5	80
		4	0.3	99
2	19	0	40.3	
		1	5.3	87
		4	4.3	89
		8	4.7	88
3	26	0	34	
		1	19.7	42
		2	10.3	70
		4	7	79
4	22	0	31.3	
		1/2	23.3	26
		4	14.3	54
5	57	0	22.3	
		2	14	37
		4	3.7	84
		8	11.7	48

(1) Dispensers set 6m apart along the vine rows. Release rate 0.1 mg/dispenser/day. Trap placed in the middle between 4 source points. Estimated mg pheromone released per dunam/day corresponding to no. of dispensers in each point: 1/2 dispenser - 2.8 mg, 1 dispenser - 5.5mg, 2 dispensers - 11 mg, 4 dispensers - 22 mg, 8 dispensers - 44 mg.

(2) Average catch of 3 traps during the test period.

Table 16. Effect of pheromone released in vineyard from Herculite units⁽¹⁾ on male GVM catch in pheromone traps⁽²⁾.

Test	Date test start	Days	Males/control trap/day	% Disruption				
				No. of Herculite units at release point				
				1/10	1	2	3	4
1	6.6.83	1-14	0.6	88.9	100			
		15-35	0.9	81.5	94.4			
		36-39	3.5	57.1	47.6			
2	5.6.83	1-9	2.2	76.0	77.7			
3	14.6.83	1-19	0.2		91.3		90.5	
		20-26	1.7		88.6		55.7	
		27-34	3.9		68.1		62.2	
4	30.6.83	1-7	7.5		82.9	78.5		
5	7.7.83	1-12	10.3		41.7			74.0
		13-25	0.4		55.0			65.0

(1) Each unit contained 40 mg pheromone releasing 1 mg/day at 25 C. Units were hung at release points every 3 m along the vine rows.

(2) Average of 3 replicated traps per treatment in Tests 1,4,5 and of 6 traps per treatment in Tests 2 and 3.

Table 17. Effect of pheromone released in vineyard from Herculite units⁽¹⁾, set at various distances along vine rows, on male GVM catch in pheromone traps⁽²⁾

Test	Date test start	Days	Males/ control trap/ day	% Disruption	
				No. of Herculit units at release points; distance between release points; equiv.gram pheromone applied per dunam.	
1	1.8.83	1-11	4.2	<u>1 unit; 3m; 4.4g</u>	<u>1/5 unit; 0.5m; 32g</u>
		12-24	9.1	71.7	83.3
		25-46	1.4	50.3	68.9
2	9.8.83	1-10	8.9	44.0	39.6
		11-22	1.9	<u>1 unit; 3m; 4.4g</u>	<u>1/2 unit; 0.5m; 80g</u>
		23-38	1.9	35.7	57.1
3	8.8.83	1-14	5.9	41.8	0
		15-37	1.8	48.3	55.1
				<u>1 unit; 3m; 4.4g</u>	<u>1/10 unit; 0.5m; 16g</u>
4	16.10.83	1-14	3.5	76.5	70.6
				79.9	66.5
				<u>1/10 unit; 0.5m; 16g</u>	<u>1/10 unit; 0.25m; 64g</u>
5	6.11.83	1-10	0.13	91.5	92.2
				<u>1/10 unit; 0.5m; 16g</u>	<u>1/10 unit; 0.25m; 64g</u>
				100	100

(1) Specification of units as described in Table 16.

(2) Average of 3 replicated traps per treatment in Tests 1,2,4 and 5 and of 6 traps per treatment in Test 3.

Table 18. Effect of Accurel spraying on GVM male catch in pheromone traps (Accurel sprayed at a quantity equivalent to 56g pheromone per dunam)

Days after treatment	Males catch/trap ⁽¹⁾	
	untreated plots	treated plots
1	0.5	0
2	1.25	0
3-4	7.5	3.75
5-6	16.5	9.5
7-8	11.5	7.25

(1) Average of 4 traps, each placed in a center of 27 m² plot

Table 19. Effect of Accurel spraying on GVM male catch in pheromone traps. (Accurel sprayed at a quantity equivalent to 16.7g pheromone per dunam)

Days after treatment	Males catch/trap ⁽¹⁾	
	untreated plots	treated plots
1	2.25	0
2-3	10.0	1.25
4	4.5	1.75
5	3.25	2.75
6	1.75	1.5

1) Average of 4 traps, each placed in a center of 27m² plot.

Table 20. Effect of GVM pheromone, released from flax⁽¹⁾ string on male trapping

Days since onset of test	3 mg pheromone/ <u>m string</u> ⁽²⁾		30 mg pheromone/ <u>m string</u> ⁽³⁾		control
	male catch/ trap ⁽⁴⁾	% inhibit.	male catch/ trap ⁽⁴⁾	% inhibit.	male catch/ trap ⁽⁴⁾
4	0.7	83.7	0	100	4.3
7	5.0	28.6	0	100	7.0
14	19.3	40.2	0.3	99.1	32.3
20	19.0	26.1	0.3	98.8	25.7
28	29.0	12.9	1.7	94.9	33.3

(1) A 1.5 mm three-ply flax string. Three strings, 6m long each, were placed parallel along 3 vine rows (distance between rows - 3m). Trap placed in the center of the middle string.

(2) Equivalent to 1g pheromone per dunam.

(3) Equivalent to 10g pheromone per dunam.

(4) Average of 3 traps.

Table 21. Effect of GVM pheromone, released from flax string⁽¹⁾, on
male trapping

Days since beginning of test	15 mg pheromone/ m string male catch/trap ⁽²⁾	30 mg pheromone/ m string male catch/trap ⁽²⁾	control male catch/trap ⁽²⁾
5	0	0	7.0
12	0	0	3.8
19	0.3	0.3	1.8
26	0	0	0.5
33	0	0.7	0.8
42	0	0	2.3
49	0	0	1.5
56	1.0	1.7	1.3
71	0	0.7	1.3
77	0.3	0	3.0

(1) See comment 1) Table 20.

(2) Average of 3 traps except of 4 traps in the control.

Table 22. The effect of different loads of GVM pheromon in flax string⁽¹⁾ on trapping of males.

Days from beginning of test	10mg pheromone/ <u>m string⁽²⁾</u>		30mg pheromone/ <u>m string⁽³⁾</u>		control
	male catch/ %		male catch/ %		male
	trap	inhibit.	trap	inhibit.	catch/tr.
8	7.6	85.9	5.0	90.7	54.0
15	18.3	65.0	8.0	84.7	52.3
22	6.3	66.3	1.3	93.0	18.7
29	8.7	55.8	1.7	91.4	19.7
36	6.0	27.7	4.3	48.2	8.3
43	16.7	38.8	8.7	68.1	27.3
50	35.3	0	18.3	25.9	24.7

(1) See comment (1) to Table 20.

(2) Equiv. pheromone applied per dunam - 3.3g.

(3) Equiv. pheromone applied per dunam - 10g.

Table 23. The effect of different density of flax string impregnated with 30 mg GVM pheromone/m on male trapping.

Days from beginning of test	<u>String every 2nd row</u> ⁽¹⁾		<u>String every row</u> ⁽²⁾		<u>Control</u>
	male catch/ trap	% inhibit.	male catch/ trap	% inhibit.	male catch /trap.
5	29.3	58.7	3.7	94.8	71.0
10	49.3	0	7.3	74.6	28.7
17	46.7	0	11.0	69.7	36.3
25	32.7	6.6	11.6	66.9	35.0

(1) Equiv. pheromone applied per dunam - 5 g.

(2) Equiv. pheromone applied per dunam - 10 g.

Table 24. The effect of different density of flax string impregnated with 30 mg GVM pheromone/m on male trapping.

Days from beginning of test	<u>String every 2nd row</u> ⁽¹⁾		<u>String every row</u> ⁽²⁾		<u>Control</u>
	male catch/ 3 traps	% inhibit.	male catch/ 3 traps	% inhibit.	male catch/ 3 traps
3	2	86.7	0	100	15.1
10	4	76.5	0	100	17.0
12	1	88.9	0	100	9.0
24	1	0	0	100	1.0

(1) Equiv. pheromone applied per dunam - 5 g.

(2) Equiv. pheromone applied per dunam - 10 g.

Table 25. Male grape vine moth catches in pheromone traps and in female traps

Treatment	Setout of pheromone traps m	Male catches in <u>pheromone traps</u>		Male catches in <u>females traps</u>	
		No./trap	No./dunam	No./trap	No./dunam
A	9 x 8	8.3	115	3.0	4.0
B	15 x 15	20.9	91	4.2	5.6
C	-	-	-	42.0	56.0

Table 26. Female grape vine moth catches in lure traps, mating incidence and cluster injury.

Treatment ⁽¹⁾	Female catches /dunam	Mated females (%)	Cluster injury(%)
A	10.8	62.5	6.0
B	7.8	51.4	9.3
C	24.0	82.9	20.6

(1) As in Table 25.

Table 27. Monthly catches of male honeydew moth in vineyard during
1982

Male catch/trap ⁽¹⁾		Male catch/trap ⁽¹⁾	
January	0	July	35
February	0	August	61
March	0.3	September	358
April	5	October	667
May	76	November	109
June	61	December	0

(1) Average of 3 traps

Table 28. Effect of honeydew moth pheromone released from flax
string⁽¹⁾ on male trapping

Days since onset of test	3 mg pheromone/m		30 mg pheromone/m		Control
	<u>string</u> ⁽²⁾		<u>string</u> ⁽³⁾		
	male catch/ trap ⁽⁴⁾	% inhibit.	male catch/ trap ⁽⁴⁾	% inhibit	Male catch/ trap
4	0	100	0	100	4.3
12	0.7	65	0	100	2.0
22	0	100	0	100	1.0
36	2.3	57	0	100	5.3
52	0	100	0	100	2.0
66	1.0	0	0	100	1.0

(1)-(4) See Table 20