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Insecticides with novel modes of action: Mechanism, selectivity, and importance in pest management programs

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Efforts have been made during the past three decades to develop selective insecticides acting specifically on biochemical sites present in particular insect groups, but whose properties differ from others. This approach has led to the discovery of compounds affecting hormonal regulation of molting e.g., ecdysteroids, juvenile hormone mimics, and chitin synthesis inhibitors. In addition, compounds that selectively interact with the insect nAChR such as the neonicotinoids have been introduced for controlling aphids and whiteflies. The search for potent acylureas has led to the development of new compounds such as chlorfluazuron and teflubenzuron, which are more potent than diflubenzuron on various agricultural pests. One of the recent benzoylphenyl ureas is the novaluron (Rimon) which is a powerful suppressor of lepidopteran pests that attack cotton and vegetables. It also controls whiteflies and leafminers. Novaluron affects larvae of *Bemisia tabaci* to a much greater extent than other benzoylphenyl ureas. Our studies indicated that the LC-50 value of novaluron on 3rd-instars *Spodoptera littoralis* fed on treated leaves is ~0.1 mg a.i./liter. This value resembles that of chlorfluazuron and is about tenfold lower than that of teflubenzuron. Artificial rain at a rate of 40 mm/h applied 5 and 24 h after treatment had no appreciable effect on the potency of novaluron. Hence, the compound is a rain-fast compound suitable for the tropics and rainy season. Novaluron has no cross resistance with other groups of insecticides and is considered to have a mild effect on natural enemies. As such, it is an important component in integrated pest management programs.

Mating induces morphological changes in the *Drosophila* female reproductive tract

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The female reproductive tract comprises of three tissues: muscle, nerve, and epithelium. Our previous genomic/proteomic analyses revealed that mating induced changes in the reproductive tract. More specifically, mating induced changes in muscle and epithelial specific proteins that contribute to the establishment of the muscle and epithelial functional identity and to the changes in transcription of genes that play key roles in development. These studies suggest that mating may play a role in the final development/differentiation of the reproductive tract. To address this question, we are conducting a morphological investigation of the reproductive tract in unmated and mated three-day-old females. Preliminary studies at the light and electron microscopic (EM) levels revealed changes in muscle, nerve and epithelium after mating. EM studies of both mated and unmated females suggest that the oviduct musculature is in a state of differentiation. Using synaptic markers and confocal imaging, we observed a 36–42% increase in the number of synaptic terminals innervating the oviduct in mated females. Taken together, these results suggest that mating induces nerve–muscle interactions that may play important roles in the final maturation of the reproductive tract. Changes in epithelium are also observed after mating. Our EM study reveals that the apical surface of the lateral oviduct epithelium gives rise to extensive microvilli that are coated in a thin layer of cuticle. In the mated female, the space between the overlying cuticle and microvilli is expanded and filled with an electron-dense, filamentous material, thus suggesting that mating may stimulate epithelial secretion in this region of the oviduct. The morphological changes observed here may play an important role in determining reproductive success.

Leishmania tropica infection rates in *Phlebotomus sergenti* by molecular detection

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Cutaneous leishmaniasis caused by *Leishmania tropica* is transmitted by the sand fly *Phlebotomus sergenti.* This zoonotic disease is prevalent in Israel, with distinct foci in the Judean Desert as well as the Tiberias region. In 2004, a *L. tropica* outbreak occurred for the first time in the town of Ma'ale Adummim (MA), expanding the western margins of the disease distribution towards Jerusalem. Sand flies are abundant in MA, and have been known as a severe nuisance for many years. The local council, supported by governmental authorities, implemented considerable control efforts. At the beginning of 2005, we started a comprehensive survey of the sand fly populations in the area as part of the governmental combined efforts to prevent leishmaniasis. We collected sand flies using CO_2 baited traps. All males and samples of the females were identified to species. *P. sergenti* comprised more than 90% of the total catch. The uniformity of the catch enables the use of pooled samples. Thus, we developed a high throughput sensitive molecular method for the parasite DNA detection in sets of 20 females. The internal transcribed spacer (ITS1) is amplified by PCR. *Leishmania* species identification is carried out by restriction of the amplified fragment. Screening large numbers of sand flies is crucial to reveal high risk locations and seasons for disease transmission.

Spiromesifen — a novel insecticide suitable for pest and resistance management programs

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Spiromesifen is an insecticide from the tetronic acids that effectively acts against whiteflies and mites. Spiromesifen acts as an inhibitor of acetyl-CoA-carboxylase, a lipid metabolism enzyme. We studied the effects of spiromesifen on the developmental stages of the whitefly *Bemisia tabaci* (Gennadius). Adult *B. tabaci* mortality was assessed by feeding adult whiteflies on treated leaves. Mortality rates reached 30% with 1000 ppm concentration. This result indicated that spiromesifen is not an effective insecticide against adults. Whitefly fecundity and fertility were assessed by exposing females to cotton leaves treated with spiromesifen. Whiteflies were then allowed to oviposit on untreated leaves. The number of eggs per female was then determined (fecundity) and the number of hatched eggs (fertility) were counted. The number of eggs laid by a single female was significantly reduced by more than 80%, suggesting a strong transovarial effect. Larval and egg mortality were assessed by direct dipping of cotton leaves on which 1st instars had developed or on which eggs had been laid. LC-50 was 0.5 ppm when 1st-instar nymph mortality was scored and 2.6 ppm when egg mortality was scored. Scanning electron microscopy showed that eggs laid by treated adult females had abnormally perforated chorion and the treated females with spiromesifen had difficulties during oviposition. Furthermore, the number of ovarioles from treated females was significantly reduced. Light microscopy showed significantly smaller eggs following treatment and the bacteriomes were smaller, abnormally formed. The effects on the endosymbiotic bacteria were observed using florescence in situ hybridization (FISH) analysis. The expression of key genes involved in lipogenesis was examined after treatment with spiromesifen. The expression of some of these genes was significantly higher when compared to the control. Finally, baseline concentrations were obtained and generally spiromesifen showed no cross resistance with other insecticides. Hence, spiromesifen could serve as an important component in pest and resistance management programs.

Essential oils from Israeli and Kenyan aromatic plants as natural fumigants against insect pests

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The wide use of synthetic fumigants, such as methyl bromide and phosphine, against insect pests has posed serious problems to human health and the environment. Thus, there is an urgent need to develop safe alternatives to toxic fumigants. Essential oils and their components are known to possess insecticidal activities and exhibit low toxicity to mammals, thereby posing them as good candidates for use in pest management. We have screened a large number of essential oils extracted from Israeli and Kenyan aromatic plants for fumigant activities against the main stored product insect and quarantine pests in cut flowers. Few very active compounds showed similar

potency as methyl bromide against the major stored product insect pests. *Sitophilus oryzae* and *Tribolium castaneum* were found to have the highest tolerance to the tested compounds. For most of the monoterpenes tested, a concentration of over 15 µl/l air was needed to obtain LC-50 of these two insects. However, concentrations of 0.5–4.0 µl/l air of SEM76, an essential oil component obtained from a Labiatae plant species, and monoterpene ketone pulegone, were high enough to obtain LC-90 of all adult species tested (compared with 30–50 g/m^3 of methyl bromide). Essential oils obtained from Kenyan aromatic plants *Ocimum gratissimum* (Lamiaceae) and *Tephrosia vogelii* (Leguminosae) showed both insecticidal and repellent activities against the main stored product insect pests. Essential oil of *Ocimum* from Kenya showed higher activity as compared to the same species from Israel. Essential oils and their constituents also showed high efficacy against quarantine insects in cut flowers such as *Frankliniella occidentalis* and *Bemisia tabaci* with no phytotoxic effects, as those observed when methyl bromide was used.

Deserticolous Noctuidae moths of Israel

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Most parts of Israel consist of semiarid and arid climate conditions that correspond with the rainless and hot period from June to September. During this period, any light sources in oases and settlements are surrounded by thousands of moths. These swarms are composed of several multivoltine and polyphagous species, while in the desert the moths are practically absent. In November and February through March, the situation is reversed. About 140 monovoltine deserticolous noctuids fly in different desert biotopes in the Arava valley, the Negev, and coastal sand dunes; these noctuids do not often visit the oases and settlements. I. "February-March species". The following species are characteristic for the Arava valley: *Polytela cliens*, and species of genus *Anumeta*: *A. spilota, A. henkei, A. atrosignata, A. straminea, A. arabiae, A. asiatica, A. hilgerti.* In the Negev, numerous Cuculliinae species are characteristic such as: *Cucullia strigicosta, Teinoptera culminifera, T. gafsana, Cleonymia jubata, C. warionis, C. pectinicornis, C. chabordis, C. fatima, Metopoceras omar, M. delicata, M. philbyi, M. solituda, M. kneuckeri. Cucullia macewani* are found on coastal sand dunes. II. Two of the spring species locally common in the southern Negev and the Arava are endophalous: *Thargelia gigantea* and *Odontelia daphnadeparisae*. Larvae of these species feed on above-ground plant parts or on roots that are 1 to 2 m deep in the soil and never show up on the surface. III. "November species". For the Arava valley, the following species are characteristic: *Scythocentropus eberti, Caradrina melanurina, Agrotis herzogi, A. haifae, A. sardzeana, A. pierreti.* In the Negev, characteristic species are: *Polymixis juditha, P. aegyptiaca, Eremopola lenis, Euxoa oranaria, Metlaouia autumna, Scythocentropus inquinata*. On coastal sand dunes: *Polymixis epiphleps, Euxoa anarmodia, Agrotis alexandriensis, A. boetica.*

Complex plant-mediated interactions between galling and folivorous insects

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Indirect, plant-mediated interactions (negative or positive) between herbivores might be common and important. We investigated such interactions between a galling aphid, *Smynthurodes betae*

(Fordinae), and the folivorus moth (*Thaumetopoea solitaria*) on the shared host tree, *Pistacia atlantica* (Anacardiaceae). The aphids induced leaf galls in early spring in which they reproduce until the fall. In the spring the moth caterpillars feed on the same leaves, occasionally leaving the plant totally defoliated ("stripped"). It is expected, therefore, that the aphids and the moths will be engaged in complex interactions, due to gall consumption and damage to the leaves that are used for gall formation and as a source of assimilates for the developing aphids. Indeed, field and laboratory experiments revealed complex interactions between the moths and the aphids: 1.The caterpillars repeatedly avoid the galls, consuming the entire leaf leaving a narrow green margin around the gall tissue ("trimmed galls") that remain intact. Feeding trials indicate that the galls are protected physically and primarily chemically from moth damage. 2. Gall density on defoliated shoots increased by about fourfold, compared to blocked (caterpillar-free) shoots. Such facilitation is based on compensatory growth of the tree following defoliation by the caterpillars, which extended the duration of availability of young leaves suitable for gall induction. 3. The reproduction of the aphids within the trimmed galls was the same as that on caterpillar-free shoot but reduced on the compensatory growth. Plant-mediated effects between the caterpillars and the aphids involve various mechanisms. The aphids manipulate the host plant (gall tissue) to avoid gall consumption and draw assimilates from alternative sources. The aphids also utilize plant response to defoliation for their own benefit.

Molecular characterization of *Bemisia tabaci* (Hemiptera: Aleyrodidae) resistance to pyriproxyfen

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During the last decade development of biorational insecticides has become frequent. These compounds have a high specificity towards target pests, and low toxicity to natural enemies and mammals. Among them is pyriproxyfen, a juvenile hormone mimic which disrupts immature stages of development. Pyriproxyfen is used to control several insect pest species including the whitefly *Bemisia tabaci*, which is a significant agricultural pest worldwide. In Israel, pyriproxyfen has been used to control *B. tabaci* since 1991; however, resistance to this compound has evolved rapidly. The mechanism of pyriproxyfen resistance in *B. tabaci* is unknown. Research in this area has been hindered due to lack of resistant and susceptible strains with common genetic background. Without common background, there is a high probability that identified genetic differences between resistant and susceptible individuals result from random genetic variation between strains rather then changes related to the resistance mechanism. To overcome this obstacle, we established a pyriproxyfen-resistant strain by recurrent selection on a susceptible strain that contained a small percentage of resistant individuals. On these "sister" strains we performed molecular analysis, searching for differences in expression patterns of metabolic genes which are capable of pyriproxyfen detoxification. We found a few genes from the cytochrome P450 family, which are over-expressed in the resistant strain relative to the susceptible strain. Over-expression of P450 genes was previously shown to play a role in *B. tabaci* resistance to insecticides from the neonicotenoide family, and in housefly resistance to pyriproxyfen. It is therefore quite likely that these genes are also involved in pyriproxyfen resistance in *B. tabaci,* but their final role is yet to be determined. Understanding of the genetic basis of pyriproxyfen resistance can lead to the development of new integrated pest management strategies for *B. tabaci* and will prolong the field efficacy of this biorational and environmentally friendly insecticide.

Taxonomic problems in the weevil genus *Brachycerus* (Curculionoidea: Brachyceridae) in Israel

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About 450 species of the genus *Brachycerus* are distributed in tropical Africa and Madagascar and an additional 50 species in western Asia and countries around the Mediterranean Sea. Most of the species inhabit arid biotopes. The species with known biology are associated with bulb plants of the families Liliaceae, Amaryllidaceae, Araceae, and Orchidaceae. About 10 species of this genus are found in Israel, constituting a rich fauna for such a small country. Two of these species are known only from the literature, and two others are apparently new to science. Of the eight species of which I have seen specimens, five are found in the Mediterranean zone, two — in the desert, and one species is found in both the coastal dunes and the inner sands of the Negev. Identification of the species in Israel was based on both external morphology and genitalia. Species recognition in *Brachycerus* is problematic due to: (1) the paucity of morphological characters; (2) interspecific uniformity coupled with large intraspecific variability; and (3) lack of knowledge on the species occurring in the neighboring countries. An article on the species of *Brachycerus* in Israel, including descriptions of the new species, an identification key, and information on the distribution and host plants in Israel, is in the final stages of preparation.

Does male presence affect female fitness? Reproductive biology of the omnivore *Orius laevigatus*

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Many studies have examined the biology of *Orius*, a biocontrol agent of many agricultural pests. However, the reproductive biology of this important natural enemy is poorly understood. This study evaluates the reproductive system, and examines implications of intergender interactions for *O. laevigatus* fitness. Male mating and insemination behaviors were tested when a virgin male copulated sequentially with 3 virgin females during 1 day or with 1 or 2 days between mating. Males proved polygamous: they successfully inseminated all the females. The total number of eggs laid by the first females to mate was significantly higher than the number laid by subsequent females. Time elapsed between matings had no significant effect on fecundity. In another experiment, female receptivity was evaluated by testing the willingness of a mated female to copulate with a virgin male 1, 7, or 14 days after first mating. Results show females to be monogamous; mated females avoided any additional mating. A further experiment was conducted to determine whether the presence of virgin males during oviposition reduces the female's fitness. In this experiment, total oviposition and hatching rate were observed for females in the presence of 0, 3, or 5 virgin males during oviposition. Controls consisted of 5 virgin females in the presence of the ovipositional females, in order to ensure that interference, if present, is caused by interactions between the sexes and not by increased *Orius* density. Total oviposition in the presence of 5 males was significantly lower than in all other treatments. Hatching success was similar in all treatments. These results show potential benefits for mass rearing of *Orius* resulting from removal of males after the first mating in order to minimize detrimental effects on fecundity and reduce rearing costs.

Prolonged ant nuptial flight as primary food source for the greater mouse-tailed bat

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During the summers of 2003–2004 we studied the diets of the greater mouse-tailed bat (*Rhinopoma microphyllum*) in northern Israel. This species migrates to this region for the summer, where the females give birth and both sexes accumulate fat reserves for the winter. Unexpectedly, from July until October ant alates of two *Camponotus* species (*C. sanctus* and *C. felah*) comprised the major part (up to 98% frequency) of these bats' diet. *Camponotus* nuptial flights are known to be brief and usually synchronized with meteorological events such as first rain or an extremely hot day, but we found *Camponotus* alates in bats feces for a continuous period of three months. Ant alates constitute a very high quality food, containing high levels of fat (>50% of dry mass) and protein. The lactation period of both *Rhinopomas* as well as a sharp increase in body mass of both sexes, is well synchronized with the emergence of *Camponotus*. We suggest that the existence of this high quality food source explains the seasonal migration of these bats to the Mediterranean area of Israel. This is the first report of such prolonged nuptial flights by Mediterranean species of *Camponotus*, and also the first report of a bat specialized in ant feeding.

Detection of and control methods for the red palm weevil in date palm offshoots

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The Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) is one of the most serious invasive pests of different palm species, including dates. Management of the RPW is problematic due to its cryptic behavior which makes it difficult to detect and control. A major route of RPW spread is via the transportation of infested planting material to new locations before the first detectable symptoms of infestation appear. It is thus imperative to develop methods and protocols for the generation of pest-free planting. The goals of this project were: to develop an acoustic based weevil detection technique and a fumigation protocol for potentially infested planting material. To address these objectives, laboratory studies were conducted under quarantine conditions. Date palm offshoots of up to 6–14 cm diameter were artificially infested with one or two 2–3rd instar larvae (20–30 mg) that were allowed to develop for various periods. Development of the larvae inside the tree trunk was monitored acoustically once a week. The effect of methyl bromide fumigation (MeBr) was tested at several doses (10, 20, 30, and 40 g/m^3) on plants infested with various weevil instars: larvae, pupae, and pharate adult. At all doses, groups of trees were exposed to MeBr treatment in gas tight dedicated chamber for 4 hours. For g/m^3, the efficacy of 4- and 8-hour fumigation was compared. A day after treatment the trees were dissected to evaluate treatment success. The fumigation with 20–40 mg/m^3 for 4 hour and 10 mg/m^3 for 8 hour proved effective in killing 100% of the weevils within the shoot. The acoustic algorithm was able to detect active

weevils with an accuracy of 97–98%. We anticipate that acoustic instrumentation and improved signal processing software will be used frequently in the future as part of a monitoring program to screen transported material.

Expression of genes involved in parasitization of *Bemisia tabaci* by *Eretmocerus mundus*

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The whitefly *Bemisia tabaci* Gennadius, and the viruses it transmits, pose a major constraint to vegetable and fiber production worldwide. Although the whitefly is best controlled using chemical pesticides, biological control agents serve as an important component in integrated pest management programs. One of these agents is the aphelinid wasp *Eretmocerus mundus* Mercet. *E. mundus* lays its egg on the leaf underneath the host nymph. First instars of the wasp hatch and penetrate the whitefly larvae in a well-organized process. The initiation of the parasitization process induces the host to form a cellular capsule around the parasitoid. Around this capsule, host epidermal cells multiply and thick layers of cuticle are deposited. The physiological and molecular processes underlying *B. tabaci–E. mundus* interactions are unknown. We used a cDNA microarray containing 6,000 ESTs from the whitefly genome to study this interaction. We compared RNA samples collected from two developmental time points of whitefly larvae parasitized during the 4th nymphal stage: when the parasitoid instar is observed underneath the host and when the instar is partially inside the host. The results clearly indicated that the conserved Toll-like pathway genes described in other insects are involved in the immune response against the parasitoid. As was previously shown in *Drosophila melanogaster*, activation of Toll pathway led to overproliferation of hemocytes, and induction of a melanization cascade initiated by the phenoloxidase enzyme. Real-time PCR analysis confirmed the microarray results and showed that the Toll pathway described in several insects and exhibits cellular immune responses including cell aggregation, phagocytosis, encapsulation of foreign material, and induction of the melanization cascade is active and conserved in whiteflies.

Bionomics of the Nile whitefly, *Aleurolobus marlatti*, in Israel

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The Nile whitefly, described as *Aleurolobus niloticus* Piesner and Hosni, was collected on *Zizyphus spina-christi* in Egypt in 1934. A second species, *Aleurolobus marlatti*, was described as a citrus pest in Japan in 1906; and in 1999 the two were synonymized as *A. marlatti.* In difference from many other whiteflies, and like other *Aleurolubus* species, *A. marlatti* immatures develop on both sides of the leaf. Its life cycle is closely associated with that of the host plant, with leaf development in the spring and summer inducing whitefly development. The goals of our research were to determine the life cycle of the whitefly in Israel and its host plants. We also examined the nymphal parasitization rates on both leaf sides. Finally, the question of whether *A. marlatti* and *A. niloticus* are the same species was examined. The whiteflies were reared on *Z. spina-christi*

and on citrus in the lab. In both cases, they preferred to oviposit under the leaf although both sides were used for oviposition. Males emerge before females and the latter are ready to lay eggs upon emergence. Infested leaves were collected from nature every 1–2 weeks and examined for nymphal location and conditions (alive, dead, or parasitized). Emergence and parasitization rates were equal on and under the leaf. Four yearly cycles developed on citrus, 3 on *Z. spina-christi*, and 3 on *Punica granatum*, although the latter is a deciduous tree. The specific identity of the whitefly is being examined using molecular tools and mating experiments.

Uncoupling fertility from fertility signaling in the honey bee, *Apis mellifera*

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Reproductive division of labor in the honeybee is mostly correlated with production of queen pheromones. Honeybees are endowed with exocrine glands that produce many caste-specific pheromones. In this study we focused on two major glands, mandibular and Dufour's gland, that exhibits caste specific secretion. However, queen pheromonal specificity is not fixed, but rather shows plasticity. In the mandibular and Dufour's glands it was demonstrated that under queenless (QL) hopeless conditions workers that possess developed ovaries concomitantly show a biochemical shift in pheromone biosynthesis from worker to queen-like chemical bouquet. In attempt to understand the mechanisms of the reproductive and pheromonal systems we attempted to uncouple ovarian development from queen-pheromone production by treating QL callow workers with methoprene (juvenile hormone analog; 150 µg topically applied per bee) that suppresses vitellogenin biosynthesis, thus inhibits ovarian development. Treated workers failed to develop ovaries, in contrast to control QL workers. Chemical analyses of Dufour's gland secretion revealed that although there was still a correlation between ovarian development and the amounts of queen-like components, their levels in the methoprene-treated bees was greater than expected from the degree of ovarian development. This suggests that methoprene did not affect ester production in the treated bees. This was not the case with the mandibular gland queen components, which showed no correlation with ovarian development, neither in the control nor the methoprene-treated workers. These results suggest that although normally ovarian development and queen-like pheromone expression in Dufour's gland are coupled, the regulatory processes operate independently.

Can liquor absinthe be an alternative to methyl bromide for stored product insect control?

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Currently used fumigants and insecticides for stored product pest control are known as high risk factors for environment and human health. Therefore it is necessary to develop safe alternatives for these chemicals. In our previous studies, the insecticidal properties of thujones were found. Two stereo isomers, alpha-thujone and beta-thujone, are the active components of essential oils of many herbs, including *Artemisia absinthium*. These compounds are active ingredients in the liquor absinthe, and in herbal medicines and seasonings for food and drinks. Absinthe was popular in the late 19th and early 20th century among Parisian artists and writers. Later it was portrayed

as a dangerous, psychoactive drug; the chemical thujone was unjustifiably blamed for most of its deleterious effects. A modern absinthe revival began in the 1990s in the European Union.

The purposes of the current study were to evaluate the fumigant activity of two stereo isomers, alpha- and beta-thujone, as possible alternatives to methyl bromide against stored product insects; and to determine whether there are some differences in the activity of two isomers against the tested insects. Adults of *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) and *Oryzaephilus surinamensis* L. (Coleoptera: Silvanidae), which are known as serious stored food pests, were used as test insects. In a space test, five concentrations of both alpha- and beta-thujone and exposure time of 24 hours were tested. Percent of insect mortality and LC-50 values were established. Both alpha- and beta-thujone were found active at low concentrations. Total mortality of *R. dominica* and *O. surinamensis* were recorded at 4.5 ml/l air and 7 ml/l air, respectively. Compared with the most active monoterpenes which were tested in similar experiments previously: SEM-76, pulegone, 1,8-cineole, carvacrol, limonene, linalool, Terpinen-4-ol, and alpha-Terpineol, the thujones were placed in the third position. The differences between the activities of two stereo isomers on the tested insects were not significant.

Developing economic injury levels for the persea mite on avocado

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The persea mite, *Oligonychus perseae*, a pest of avocado originating from Central America, was first discovered in Israel in the autumn of 2001 in several avocado plots in the Western Galilee. It has since spread to most of the avocado growing areas in the country. Because no damage threshold is available for this pest, some growers apply up to four acaricide treatments per year, while others will not spray at all, often resulting in extensive foliar damage. To reduce pesticide use on the one hand and prevent damage to fruit quality and yield on the other, the aim of the present study was to develop an action threshold for this pest. We created four pest densities on Hass trees, by keeping an unsprayed control and applying spirodiclofen and abamectin acaricides at 50, 100, 250 mites/leaf. The study was conducted during three consecutive growing seasons (2004–2006), with six replicates in randomized complete block design. Leaf damage and yields were evaluated in 2005–2007. Based on cumulative mite days, the plots sprayed at 50 and 100 mites/leaf were similar with respect to damage and yield, and differed significantly ($p = 0.03$) from those in the two higher mite densities, which did not differ from each other. Mite population levels significantly affected leaf damage and mean tri-annual yields (2005–2007). At the higher mite population levels, mean yield was reduced by 20% in comparison to the mean yield attained when plots were sprayed at a threshold of 50–100 mites per leaf. *O. perseae* is an economic pest that must be dealt with; action threshold of 50–100 mites/leaf can be adopted at least as a starting point; future refining of this action threshold can be expected.

Ammonia-releasing substances as potential interfering agents to poison-bait spray applications against the Mediterranean fruit fly, *Ceratitis capitata*

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The most common control procedure against fruit flies is low volume aerial or ground spraying of a blend containing insecticide and protein-based bait, since fruit fly females need an external source of protein for sexual maturation. The role of the bait in this mixture is to reduce the amount of pesticide, thus decreasing environmental contamination as well as financial costs. Gaseous ammonia is the major component end-product of decomposition of any biological matter. It was proved and defined by us that ammonia is the main factor in attracting the flies toward the protein-based bait, an attraction that is dose-dependent. We have tested and compared the attractiveness of two classes of ammonia-releasing compounds to the medfly, commercial baits and conventional materials being routinely used during orchard management such as manures and fertilizers. In most cases the proteinaceous baits were inferior to the manures and the fertilizers. Females' need for protein is expressed by the level of attraction toward any ammonia-releasing source. Females which had an access to poultry litter were less eager to reach the most attractive ammonia solution as compared to protein-deprived females. Poultry litter contains about 16% true protein, which, probably, provides some of the protein needed for sexual maturation. Ammonia-releasing compounds, natural as well as those that are used for agricultural purposes, are widespread in orchard habitats and therefore may compete with the poison bait sprays, a point that should be taken into consideration during fruit fly control applications.

The number of sons of mated females is higher than of virgin females in a polyembryonic parasitoid

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Polyembryony is the development of a clone of genetically identical individuals from a single egg by repeated proliferation. In polyembryonic parasitoids, the number of offspring per clone is variable and affects the fitness of both parents and offspring. Since the optimal number of offspring differs between parents and offspring, it is interesting to study the function of parents and offspring in regulating clone size. In the parasitoid wasp *Copidosoma koehleri* (Hymenoptera: Encyrtidae), female clones (developing from fertilized diploid eggs) contain more individuals than male clones (developing from unfertilized haploid eggs). Perhaps the female offspring's diploid genome enables them to proliferate more than males. Alternatively, parental mating may lead to physiological change in the egg that is expressed in increased proliferation. We evaluated these hypotheses by comparing male offspring of virgin and mated females. The first hypothesis predicts an equal number of male offspring of mated and virgin females. The second hypothesis predicts a lower clone size for offspring of virgin females than for offspring of mated females. We collected wasps from female clones and mated half of them. Each mated and virgin female oviposited once into a host, *Phthorimaea operculella* (Lepidoptera: Gelechiidae). Emerging offspring were counted and sexed. The number of sons of mated females (n = 14) was significantly higher than the number of sons of virgin females (n = 23).This finding shows that clone size of offspring of a mated female

is higher than that of a virgin female, whether she lays males or females. These results support the hypothesis that mating leads to increased proliferation. The increased proliferation may comprise a male strategy to enlarge the number of its offspring if the female uses its sperm, but is also expressed when the female oviposits unfertilized eggs. Increased clonal proliferation may also enhance maternal fitness. We will discuss these interpretations.

The agricultural landscape influence on spider assemblages in nearby natural areas in a desert agro-ecosystem

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The agro-ecosystem combines agricultural and natural habitats and is characterized by spatial and temporal heterogeneity. Desert agro-ecosystems, unlike those in temperate regions, are characterized by extreme differences between natural habitats and cultivated fields due to different biotic and abiotic conditions. These differences between the habitats cause sharp boundaries between the habitats, which affect the organism movement between the habitats ("edge effect"). The edge effect and the different characters of the spider influence the spider habitat preference and result in distinct spider assemblages. Habitat-specialist spiders are not able to cross the edge and will be found in one habitat, while habitat-generalist spiders that are able to cross the edge will be found in both habitats. Research on such agro-ecosystems reveals that landscape composition (heterogeneity and percentage of natural habitat in 1 km radius) can influence the diversity of arthropods, including the spider community in the agricultural habitat. In this research we tested the different factors (landscape composition and biotic and abiotic factors) and their influence on the spider assemblages in the natural habitat, and the factors that affect the habitat preference of common species. We found that the spider distribution was not affected by the landscape composition but there was an effect of biotic and abiotic factors on the distribution of the different spider species.

Advances in locust phase research

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Locusts are acridids that form huge aggregations at irregular periods and exhibit continuous density-dependent phase polyphenism. There are two phases: solitarious and gregarious, with intermediate (transiens) forms between them. Over one hundred phase-dependent differences exist; they are connoted as "phase characteristics". The nymphal coloration is one of the most conspicuous and well discernible phase characteristic. Recently, a dark-color-inducing neurohormone (= [His^7]-corazonin), a blocked undecapeptide, was discovered by employing an albino strain in which this neurohormone is absent. Depending on dose and timing, this neurohormone induces either dark patterns, typical to gregarious nymphs, or dark coloration, typical to homochrome solitarious nymphs. Increasing population density (crowding) is the primary factor in

gregarization; the first effect is behavioral changes. Gregarious locusts aggregate and they are more active than solitarious locusts, which avoid crowding. However, in contact with a crowd, solitarious locusts quickly (within hours) change their behavior and join the crowd. Recent research, in several laboratories, revealed various signals that induce/amplify gregarization in the desert locust (*Schistocerca gregaria*); these signals are olfactory-volatile, contact chemical, contact mechanical (tactile), and visual stimuli, as well as a chemical factor in the egg pod foam that induces gregarization of the hatchlings. These stimuli and their role in gregarization, often with controversial claims, will be discussed.

Methods for the development of control of *Capnodis* spp. larvae by using selective products

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Capnodis tenebrionis Linnaeus and *C. carbonaria* Klug (Coleoptera; Buprestidae) are the main pests in stone-fruit orchards in Israel. The commonly used methods to control these pests are based on extensive use of organophosphates and carbamates against adults. There is no known commercial, efficient means to control eggs located in the soil and larvae located in the roots. In this study the possibility of preventing larvae of *C. tenebrionis* from penetrating the roots by using various ground covers was tested. In laboratory experiments using individual larvae assays, none of the larvae managed to penetrate the sheets of "Super Silver Agripal 100" (SSA) and "Black Agripal 100" (BA). From the "Black–White Agripal 130" (BWA) 45% larvae penetrated, and 85% in the control (soil only without ground cover). Using a mass test system the penetration rate was 0%, 4.7%, 27.4%, and 44% in SSA, BA, BWA, and control (soil 5 cm high without ground cover), respectively. In conclusion, SSA gave the best protection. In the future we will test the potential use of the ground cover, SSA, directly on the host plant in the greenhouse. It is hypothesized that the neonates will penetrate the soil and will be blocked by the ground cover and will not infect the roots. Success with this method will improve the *Capnodis* spp. long term management control and will enable the development of IPM in stone-fruits orchards.

Host–parasitoid relations between *Daphnis nerii* (Lepidoptera: Sphingidae) and *Cotesia saltator* (Hymenoptera: Braconidae)

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Host–parasitoid relations were studied between *Daphnis nerii* (Sphingidae) and its parasitoid, *Cotesia saltator* (Braconidae). Parasitism levels were determined by collecting *D. nerii* larvae from the field and exposing lab-reared larvae for a few days in Tel Aviv and at Nahal Oren to compare parasitism between urban and wild areas. Parasitoid sex ratio and the occurrence of additional parasitoid species were recorded. *C. saltator* was present in high numbers from mid-June to mid-October. Parasitism rates, about 50%, were relatively constant except for the second year, when no parasitoids emerged from larvae in the urban area during July, although they reappeared in August. Three additional species of parasitoids were found, two species of Tachinids and *Mesochorus* sp. Intraspecific host discrimination and superparasitism avoidance were studied in

C. saltator females. Naive females were offered alternately unparasitized and parasitized hosts 0, 24, or 48 hours following initial parasitization by another female. Some of the females were used twice to determine whether a learning process occurs. Superparasitism levels (through dissection) and host encounters were recorded. Females discriminated between parasitized and unparasitized hosts and generally avoided superparasitism. The number of encounters with parasitized hosts was significantly higher. Twice-used females did not exhibit significant differences between the first and second experiment. Additionally, naive females were offered either unparasitized or parasitized hosts only, one at a time. Unparasitized hosts were almost always parasitized during the experiment, but most of the females avoided superparasitism to some extent and parasitized only some of the already parasitized hosts, suggesting that the ability to discriminate in this species is innate and remains constant at different times after the first parasitization.

Phenotypic variation and plasticity in the antlion *Myrmeleon hyalinus* populations

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Israel is characterized by sharp climatic gradients, from Mediterranean climate in the north to desert climate in the south. We performed a transplant experiment to compare life history and morphology among five antlion populations along this gradient. Larvae were raised in two environmental chambers (ECs), simulating Mediterranean and desert climates. Larvae either from Mediterranean populations or which were raised in the Mediterranean EC grew more slowly and pupated at larger mass compared to desert populations or desert EC. Mediterranean populations showed larger differences in pupation and mortality rates between the ECs compared to desert populations, which showed a fixed response, independent of climate. The ontogenetic morphological change and the morphological differences among populations were described by analyzing larval digital photos. The three instar stages were statistically distinct. During ontogeny, the head becomes relatively larger, the mandibles shorter and wider, and both head and mandibles increase in relative size, when taking the abdomen as a reference. Differences among populations usually indicated a decrease in trait size along the north–south gradient, in accord with the decrease in the final mass before pupation. In conclusion, we show here how climatic gradients translate into phenotypic differences in an antlion population and provide a morphometric tool to distinguish among instar stages.

Noctuidae (Lepidoptera): Status of pest-species in Israel

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The Noctuidae constitute the largest family of Lepidoptera, including more than 35,000 known species (an additional 65,000 species are still expected to be discovered), belonging to more than 4,200 genera. Noctuidae larvae are phytophagous on a wide range of plant species. The larvae feed at night and rest during the day either in the soil or in crevices of the plant. Most of the species develop on wild plants, but some are agricultural and horticultural pests. For example, cutworms eat the bases of young plants, and bollworms damage the reproductive organs of plants. Some

species are known to be severe pests that cause annual damage to crops, while some others are minor pests that appear sporadically on crops. The number of species and list of pests in Israel needs to be clarified because some were recorded many years ago only once or sporadically on crops. Presently, 549 species of Noctuidae have been recorded in Israel. Forty-five species (8.2%) are known pests, or have been recorded as pests in the past. Ten species (1.8%) are severe pests, 15 species (2.7%) are minor pests, and 20 species (3.6%) are potential pests.

Effect of shrub–open mosaic on beetle community

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Understanding the processes that determine species diversity is of great concern. The massive loss of biodiversity in the last centuries may threaten the functioning and stability of ecosystems. Considerable progress has been made in the last decades in addressing the role of landscape diversity in environmental processes. This research relates to the two-phase mosaic made by shrubs and inter-shrub patches as a simple form of landscape diversity and aims to study its effect on ground-dwelling beetle diversity. The difference between the two mosaic phases is defined as "contrast" and includes environmental contrast (of properties such as temperature, moisture, and accumulated organic matter) and diversity contrast (species richness, abundance, and composition). I studied the effect of structural contrast on environmental contrast and on diversity contrast. The study was performed in two long-term ecological research (LTER) stations in Avdat (arid ecosystem) and Lehavim (semiarid), Israel. Shrubs were removed to study their effect. Beetles were sampled by pitfall traps. One hundred and twenty-four species were identified in Avdat, and 125 species in Lehavim. In Avdat, Tenebrionidae was the dominant family (50% of total abundance) out of 30 families. In Lehavim, Tenebrionidae (52%) and Carabidae (15%) were the dominant families out of 29 families. Results show that in both sites shrubs provide resource contrast as more organic matter accumulates under shrubs compared to open patches. This measured contrast was not perceived by the beetles, which showed opposite trends in the different sites: In Avdat, beetles were more active under shrub patches and in Lehavim in the open patches. Findings offer that mosaic of shrubs and open patches affects beetle diversity, probably by ecosystem engineering, which affects environmental contrasts. To explore the behavioral mechanism behind these patterns further field observations in beetle activity and measurements of environmental contrast are planned.

Natural plasticity in circadian rhythms is mediated by reorganization in the molecular clockwork in the honeybee

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Most animals cannot sustain long lasting periods of activity without circadian rhythms. However, some animals are active around-the-clock for extended periods without apparent ill effects. In honeybees (*Apis mellifera*) plasticity in circadian rhythms is socially modulated and associated with the division of labor that organizes their colonies. "Nurse" bees (typically <2 wk of age) care for brood around the clock whereas foragers (typically >3 wk of age) have strong circadian rhythms that are necessary for sun compass navigation and timing visits to flowers. We combined behavioral and molecular approaches in our study on the molecular underpinning governing this naturally occurring chronobiological plasticity. We found that nurse bees care for brood around the clock

even when experiencing a light/dark illumination regime. Brain oscillations in the abundance of the putative clock genes *Period* and *Cryptochrom-m* were attenuated or totally suppressed in nurses as compared to foragers, irrespective of the illumination regime. However, nurses showed circadian rhythms in locomotor activity shortly after transfer from the hive to individual cages in constant laboratory conditions. The onset of their activity occurred at the subjective morning. These data suggest that some clock components were entrained even in nurses, active around the clock while in the hive. Nurses removed from the hive and kept in cages for ≥8 hours before sampling every 4 hours for molecular analyses showed weak cycling in *Per* and weak or no cycling in *Cry* mRNA abundance. Nurses kept in cages for ≥16 hours showed stronger *Cry* mRNA cycling compared to sister nurses sampled from the same hive. These findings support the hypothesis that natural plasticity in circadian rhythms of honeybees is associated with environmentally regulated plasticity in the molecular clockwork.

Changes in beetle diversity along a rainfall gradient in Israel

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This study explores changes in beetle ground fauna in four study sites along the north–south aridity gradient in Israel. Climate change scenarios (increasing or decreasing rainfall in winter) were tested at two stations (Mediterranean and semiarid ecosystems) using experimentally droughted and irrigated plots. We used pitfall traps with a diameter of 10 cm filled with propylene glycol. In each study site, 60 traps were established. Each was opened for five consecutive days. Two main habitats were studied: (1) open gaps between shrubs and (2) shrub understory. The area of each pitfall was considered so as to study the relationship between microhabitat and sample data. The beetles collected were identified to the species level. We present here our preliminary results from the spring (March and May) 2006, summer (June) 2006, and winter (February) 2007 sampling seasons: (1) Significant differences in abundance and species richness of beetles were found among stations and between seasons. Some beetle species were collected only in the north while others only in the south. (2) No significant differences in abundance and species richness of beetles were found at the rainfall-manipulated plots on the two central research stations. Nevertheless, a slight trend was noted in particular seasons in different stations. (3) Positive interactions were found between site and sampling season for different beetle families. In general, significant differences in species composition were found between the research stations along rainfall gradient and between seasons. We believe that changes in rainfall, food availability, community structure, and soil type are the main drivers responsible for these changes. Further analysis considering the interactions among these drivers is required in order to understand the factors regulating beetle biodiversity in this region. The study will continue in order to build a more complete picture of beetle biodiversity along the rainfall gradient in Israel.

Evaluation of natural and synthetic area repellents as a method for indoor sand fly (Diptera: Psychodidae) control

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Sand flies are vectors for the *Leishmania* parasite, which can cause cutaneous leishmaniasis. In addition, their bites comprise a nuisance, and constitute a health risk. Sand fly breeding sites are very difficult to identify and access, making larval control almost impossible. Therefore control efforts focus on adult sand flies around human habitats. In this research we are testing methods for controlling sand flies and reducing the bites burden in human habitats, by using natural (geraniol) and synthetic (the pyrethroid prallethrin) repellents. Results indicate that geraniol did not reduce the number of sand flies entering houses and did not reduce the biting rate. Geraniol had no effect on blood gorging of laboratory-reared sand flies allowed to feed on chicken. Perhaps a higher dosage of geraniol may provide better results in deterring sand flies. In the current summer season we will conduct a controlled field experiment to evaluate the potential of different dosage of geraniol, as an area repellent used against phlebotomine sand flies. In addition, prallethrin was efficient as an insecticide at laboratory. Results indicate prallethrin efficacy ($p < 0.01$) in deterring sand flies from houses. This research is a part of an integrated effort of sand fly control. We predict a decrease in sand flies' biting burden when integrating several control methods.

Investigations into the viability of remote sensing as a management tool for gall wasp, *Ophelimus maskelli* Ashmead, infestations of eucalyptus trees

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In the last decade the eucalyptus gall wasp, *Ophelimus maskelli*, Ashmead (Hymenoptera: Eulophidae), has invaded the Mediterranean region. The wasp was first detected in Israel in 2003. It induces leaf galls on several species of eucalyptus trees. The injury is revealed by foliage desiccation and premature shedding of the leaves. We evaluated the viability of using remote sensing as a tool for early detection and managing eucalyptus stands infested by the wasp. The level of analysis that is usually recommended in the early understanding and development of methods leading to remote sensing is at leaf and sapling levels. In this study, spectral reflectance of healthy and infested galled leaves and saplings were measured in the visible and near infra-red regions of the electromagnetic spectrum using a hand held spectrometer. The effect of different types of stress caused by galling on the spectral reflectance curves was also studied i.e., age of galling, density of galling per leaf, and percent of necrosis per leaf. The analysis for the resulting spectral curves focused on the red edge region (680–780 nm) mostly used in remote sensing to detect stress in vegetation. The results indicate that there are significant differences between galled and non-galled leaves in the red edge region. These differences are the wavelengths where the maximum value of the derivative curve in the red edge region occurs. Wavelengths tended to be generally lower in galled leaves and saplings compared to non-galled leaves and these findings suggest that although remote sensing may not be viable as an early detection tool for the gall wasp, it seems to have potential use for differentiating between galled and non-galled trees in eucalyptus stands. This discerning ability of remote sensing can provide quantitative information of galling infestation levels as well as spatial extents of injury.

Biological control of the olive fruit fly in Israel

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The olive fruit fly, *Bactrocera oleae*, is a key pest in olive orchards along the Mediterranean basin. The current techniques used in plant protection against this pest in Israel include organo-phosphorous insecticides and mass trapping. The purpose of this study is to evaluate the use of biological control as an additional means of protection against the fly. In order to find the composition of natural enemies attacking the fly in Israel we conducted a field survey in orchards and private gardens during the end of the olive season in 2006. A single species of parasitoid wasps, *Psyttalia concolor*, emerged from infested olives at a wide geographic distribution, and its population density was in a positive correlation to that of the fly. We also found the olive midge, *Lasioptera berlesiana*, which is reported as a natural enemy of the fly. We continued our survey at the beginning of the 2007 season, and found several additional species of parasitoid wasps that emerged out of olives. Most of them have not been identified yet. Because the presence of sugar increases *P. concolor's* fitness in the lab, it is possible that the presence of nectar-providing plants in the orchard would increase its fitness and function as a biological control agent. In order to perform an initial screening of candidate plants as cover crops, we tested in the lab the effect of three plants, *Ricinus communis, Foeniculum vulgare*, and *Medicago spp*. on *P. concolor*'s fitness. Next steps would be testing if sugar is a limiting resource for this wasp in the orchard, and if the presence of these plants in the orchard would lead to improved biological control.

Amblyseius swirskii as a biological control agent of *Polyphagotarsonemus latus* in sweet pepper in the Arava Valley

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The broad mite, *Polyphagotarsonemus latus*, is a major pest on many crops in tropical and subtropical regions and in greenhouses world-wide. The phytoseiid predatory mite, *Amblyseius swirskii,* is able to feed on a wide range of arthropods and pollen. In earlier laboratory experiments on leaf-discs, we demonstrated a positive correlation between increasing population densities of *P. latus* and consumption rate by the predatory mite *A. swirskii.* Based on these positive results we moved to field trials to determine the predator's ability to control broad mites in covered sweet peppers. Sixteen walk-in tunnels were planted with sweet pepper seedlings; predators were released at two rates, 50 and 100/m^2, and were compared to non-treated and acaricide-treated controls. There were four replications for each treatment in a randomized block design. Samples of leaves and flowers from each tunnel were taken weekly and the presence of all mites was examined in the laboratory. The higher predator release rate was comparable to the acaricide treatment in the level of broad mites control and the quantity of fruit for export. Plants in the lower release rate were stunted from the broad mites and had fewer export quality fruit. Our observations indicate that 100 predators/m^2 is the recommended release rate for the hot and dry Arava Valley conditions.

Blood meal identification in sand fly vectors of *Leishmania*

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Blood meal identification from field-caught engorged female sand flies is an important approach in defining host preferences and pointing to a possible reservoir species. In the Judean Desert the sand fly vector of *Leishmania tropica* is *Phlebotomus sergenti*. The incentive to develop a method for blood meal identification derives from the lack of satisfactory confirmation of the suspected animal reservoir — the wild rock hyrax. The recent progress in molecular techniques enables accurate characterization of the blood source within the arthropod gut, based on DNA analysis. We developed a PCR-based technique followed by DNA sequencing for identification of blood meals in sand flies regardless of prior knowledge of host occurrence. The PCR primers were designed to amplify mitochondrial 12S and 16S ribosomal genes of vertebrates, and not to amplify arthropod DNA. The final step of the blood identification is carried out analyzing the DNA sequence of species-specific non-conserved regions of the amplified fragment. Using this method we identified the hosts of 300 engorged females collected in the Judean Desert and Tiberius during 2005–2006. Co-analyzing the host preferences and leishmania infection results, enabled us to point to the reservoir animals with a high degree of confidence. This method of blood meal identification is universal and can be applied to any blood-sucking arthropod.

The little fire ants' impact on other ants' species

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Invasive species are considered the second major cause for biodiversity decline worldwide. The little fire ant (LFA), *Wasmannia auropunctata*, is an aggressive invader, and may provide the opportunity to study the mechanism of invasion. LFA arrived to Israel about ten years ago, probably from South America, and until now it was found in 13 localities in Israel. In order to study the ants' impact on arthropod communities in Israel, we carried out a comparative study using pitfall traps and baits in areas with different densities of the LFA. We found a significant impact of LFA presence on other ant species' abundances, on ant species richness, and on spider abundances. In light of these results, we decided to study the behavioral cause for the ants' success. We conducted laboratory experiments in order to compare the foraging abilities of LFA and other non-native species that were displaced by LFA. We found that when there is no between-species interference. *Monomorium subopacum* workers locate food faster and retrieve more food to their nest than those of *W. auropunctata*, possibly due to their faster movement. Unlike most ant species, which show high aggression towards conspecifics, invasive species usually do not show any intraspecific aggression, forming a colony structure called unicoloniality. It is believed that lack of intraspecific aggression enables the ants to use their resources in order to produce high population densities and therefore to gain an advantage in interspecific aggression. In laboratory aggression tests we found no intraspecific aggression between nests from different villages, compared to high interspecific aggression. It is possible that although LFA has poorer foraging strategies, the numerical advantage it gets from its distinctive colony structure enables it to successfully displace other ant species.

The invasive mosquito, *Aedes albopictus*, a newly established pest to humans in Israel

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Aedes albopictus, adults and larvae, were first recorded in Israel in summer 2002 in Moshav Ginnaton, near Lod, associated with used tires. *Aedes albopictus*, a vector of dengue fever, has spread from Asia to the Americas, Africa, Europe, Lebanon, and Syria. Their flying range is very short, and they apparently spread mainly through the used car–tire trade. The easily identifiable adult is black with brilliant white stripes. Large populations are a severe nuisance and difficult to control. Following the first findings, a survey carried out in 2002 revealed adult mosquitoes at 9 coastal plain sites from Rechovot to Kabri. Subsequently, this species was found at 9 additional coastal plain sites and in 3 Upper Galilee sites. Trappings using CO_2 and light caught only a few specimens of *A. albopictus*, which are day-active. Monitoring the breeding sites of very small water bodies and receptacles is problematic and cannot indicate the population density. The number of citizens complaining of daytime bites, and adults collected from inside houses, mainly in urban areas, is steadily increasing, indicating an increase in population levels. Since its invasion to Europe in 1979, there have been no reports of dengue transmission. *Aedes aegypti*, the main vector of dengue worldwide, was common in Israel till the 1940s but has now disappeared, and we do not definitely know whether dengue was ever present here. *A. albopictus* tested for west Nile virus by the Virology Laboratory (Ministry of Health), proved negative. The main problem of *A. albopictus* control is the numerous, small, cryptic breeding sites spread over large areas. Therefore, the only viable control method of this mosquito is dissemination of information enabling the citizens to dry out or remove each small breeding site in their own areas and to continue with vigilant surveillance.

Interactions between queens of the little fire ant, *Wasmannia auropunctata* — behavioral and chemical aspects

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The little fire ant (LFA), *Wasmannia auropunctata*, is an invasive species that arrived to Israel 8 years ago to Kibbutz Afikim in the Jordan valley, and has since spread to other localities in Israel. In its invasive range the ant is characterized by the lack of intra-specific aggression, resulting in "super colonies" which contain multiple queens (polygynous). The mode of reproduction of this species in its invasive range is peculiar in that all queens are produced by thelytoky and are clones of the mother queen, whereas the males originate from diploid embryo from which the mother genome is excluded and therefore are clones of their father. Workers are the only caste that is heterozygote. Polygyny may result in a reproductive conflict between queens that are trying to achieve a genetic predominance by suppressing the reproduction developments of other queens. Our research objectives are to examine whether the genetically identical queens of the LFA are equally fertile and are equally attractive to workers. Preliminary data indicate that despite being clones, queens show phenotypic variation in fecundity, which is positively correlated with their weight. Moreover, heavier queens attract more workers to their surroundings. These observations raise the question of how workers are able to estimate queen fertility. We hypothesize that this is achieve by perception of putative fertility signals emitted by the queens. To test this hypothesis we examine the chemical composition of two glandular sources, the postpharyngeal and Dufour's

glands. Differences in the secretionary composition of both glands were found between queens with different fertility status.

Variability of the genetic and phenotypic diversity of darkling beetle populations along geographical gradient in Israel

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Population diversity, an important level of biodiversity, can be measured as variation in the genetic and phenotypic makeup of populations along geographical and ecological gradients. The degree of such variation is strongly affected by both spatial and temporal variability. We conducted a field study on beetle populations inhabiting the fragmented landscape of the southern Judean lowland in Israel. To control for the effect of spatial heterogeneity, we sampled different populations of a generalist and highly abundant darkling beetle species along a steep climatic gradient where fragmentation intensity was approximately the same. We found that beetle genetic and phenotypic diversity were positively correlated with temporal weather variability at the monthly and seasonal scales. Nevertheless, genetic differentiation among these populations was moderate, suggesting that gene flow is not restricted along this geographical gradient. Classical literature referring to the interplay between population diversity and temporal variability has examined temporal weather variation at the yearly scale. However, this time scale may be problematic when investigating univoltine species, which often respond to shorter scales such as season or month as presented in our study. We thus suggest that to better understand how an organism perceives the environment it is necessary to examine its response to varying temporal scales.

Phagostimulation of carbohydrates and protein hydrolyzates in the adult Ethiopian fruit fly, *Dacus ciliatus*

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The Ethiopian fruit fly (EFF) *Dacus ciliatus* (Diptera) belongs to fruit flies family Tephritidae and is classified as an A1 quarantine pest by the European and Mediterranean Plant Protection Organization. In Israel, the fly is present and restricted to the Arava valley, where it has been contained for several years by a strict control protocol. The fly attacks and develops on wild and cultivated cucurbits. Substances that stimulate ingestion are denominated phagostimulants. The phagostimulative properties of substances may vary with fruit fly age, sex, nutritional status, and activity. Little information exists to date on the phagostimulative and nutritional properties of food for the EFF. This type of information is required in order to develop control methods and strategies such as "lure and kill" and SIT. Specifically, phagostimulative and nutritional information of food substances may serve in the development of mass-trapping devices (e.g., efficient arrestant substances) and in the improvement of artificial diets required for mass-rearing. The present study investigated the phagostimulative properties of several carbohydrates and protein hydrolyzates and how these properties are affected by sex and age. Phagostimulation was studied on individual flies using the PUB (Phagostimulation Unit Bioassay) method. Amongst the tested carbohydrates

solution (glucose, sucrose, fructose, and lactose in two different concentrations, 5% and 10%), 5% fructose was found as a significant phagostimulant in both female and male EFF. Regarding flies maintained on carbohydrates solutions, no differential mortality during the first 10 days of adult life was detected. In contrast to other tested carbohydrates, fructose intake and phagostimulation through the pre-sexual stage of the fly was significantly high during early adult age. Protein hydrolyzate solution (without carbohydrates) did not showed any (or very low) phagostimulative activity, and flies tested on these solution died within few days after eclosion. Apparently protein hydrolyzate solutions induce water loss in the fly, and premature death.

The feasibility of harvesting unifloral honeys in Israel

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Israel is characterized by a large diversity of vegetation in a limited area, which raises the question as to the feasibility of producing unifloral honeys. We characterized eight local honeys and assessed whether they were unifloral based on melissopalynology. Honeys were from three types of landscape: (1) Natural vegetation represented by ziziphus (*Ziziphus spina-christi*) and Jaffa scabious (*Cephalaria joppensis*); (2) Planted woods represented by eucalyptus (*Eucalyptus sp.*), tamarisk (*Tamarix sp*.), and carob (*Ceratonia siliqua*); (3) Agricultural landscapes represented by citrus (*Citrus* sp.), cotton (*Gossypium* sp.), and avocado (*Persea americana*). Avocado honey was also analyzed for perseitol, a unique marker for this honey. Among the natural vegetation honeys, none contained the respective pollen as a predominant pollen source (>45%). The respective pollen was a minor one (10%–15%) in most ziziphus honey samples, and it was only 1% in the scabious honey. In contrast, the respective pollens were the predominant ones in most of the honey samples obtained from planted woods. Honeys from agricultural landscapes did not contain predominant pollen of the target crop. However in these crops the proportion of the relevant pollen in honey is known to underrepresent the proportion of the relevant nectar. We estimated the relative contribution of avocado nectar by comparing between perseitol concentrations in the honey and those in nectar. This analysis revealed that the avocado honey was unifloral, despite its minor (14%) avocado pollen contents. This study illustrates some of the difficulties involved in harvesting unifloral honeys where vegetation patches are relatively small and heterogeneous, such as in Israel. We could not conclude that the honeys from the natural vegetation were unifloral. However, we show the feasibility of obtaining unifloral honeys from managed landscapes such as planted woods and agricultural plots, even though these are usually limited in size.

Host feeding in the parasitoid *Eretmocerus mundus* (Hymenoptera: Aphelinidae)

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The parasitoid *Eretmocerus mundus* Mercet (Hymenoptera: Aphelinidae) is a solitary parasitoid of whitefly nymphs. The eggs are laid on the leaf and the larva penetrates its host and develops there to adulthood. *Eretmocerus mundus* is synovigenic, i.e., it emerges from the pupa with only some of its egg complement. In order to mature more eggs during its adult life the females feed

on host body fluids (= host feeding). The purpose of this research is to investigate the host feeding process and its necessity. We used three categories: Normal host feeding, preventing host feeding altogether, and feeding the wasp alternative proteins in order to determine their effect on the wasp's performance. We also examined the larval instar which the wasp prefers for host stinging, and the time in its life cycle in which she will host feed. Here we will focus on the question of the preferred whitefly nymphal instar for host feeding. Each experiment included 3 observations, one per day, during 3 continuous days, each lasting 1.5 hours. The treatments included wasps of all 3 categories, which allowed us to estimate if the treatments would change the females' behavior. In every experiment we measured the sizes of the larvae that had been stung for host feeding to determine their instar. In all cases the preferred instars were the second and third nymphal instars. The results showed no treatment effects, i.e., no differences in larval sizes.

Identification of some host attractants for the Ethiopian fruit fly, *Dacus ciliatus* Loew (Diptera: Tephritidae)

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The Ethiopian fruit fly, *Dacus ciliatus*, is an oligophagous, EPPO (European Plant Protection Organization) quarantine pest of cucurbit crops, especially of melons, cucumbers, and marrows. Specific attractants for this pest are unknown. The present study aimed at identifying attractants for *D. ciliatus* derived from different host and non-host fruits. The identification process was guided by two types of bioassay: a choice-test behavioral bioassay that was especially developed for screening plant volatile preparations against carrying-solvent, and fly antennal response to the separated volatile components in GC-EAD (gas chromatography — electro antenno detector system). Both sexes were tested in the two bioassays under controlled conditions. Plant volatiles were collected on Super Q or Activated Carbon packed columns from jars containing the fruits and eluted with hexane. We screened fruit volatile extracts from different host-plants (e.g., zucchini, *Cucurbita pepo*; melon, *Cucumis melo*) as well as non-hosts (e.g., strawberry, *Fragaria* sp.; banana, *Musa* sp. ;and tomato, *Lycopersicon esculentum*). Among the host volatile preparations tested, melon volatiles were consistently attractive to both sexes of *D. ciliatus*. Antennae of both sexes responded positively in GC-EAD to some ripe melon volatiles. Among the bioactive compounds, *E*-β-farnesene, *Z*3-octenyl acetate and octyl acetate were identified using GC-MS libraries, retention indices and authentic standards. The attractiveness of synthetic compounds of the two acetates and *E*-β-farnesene was confirmed by GC-EAD. In behavioral bioassay, *Z*3-octenyl acetate and octyl acetate tested individually showed dose–response attraction patterns to both sexes of the fly, whereas flies were not attracted to *E*-β-farnesene at tested doses. We plan to advance the development of efficient synthetic lures by identifying additional responsive ingredients and by studying the interactions between the bioactive components.

Dufour's gland secretion in *Bombus terrestris*: an informative tool to assess individuals in the colony

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Worker reproduction in the eusocial bee *Bombus terrestris* occurs in queenless (OL) colonies or in queenright (QR) colonies at the competition phase (Cph), about a month after first worker

emergence. The colony operates in harmony until the Cph, presumably due to the inhibitory or restraining effects of a putative queen pheromone on workers reproduction. At the Cph, the inhibitory effect of the queen becomes less effective, resulting in overt queen–worker as well as worker–worker aggression and competition over male reproduction. Dufour's gland secretion in *B. terrestris* is caste specific; workers possess esters that are absent in queens or egg-laying workers. The esters are most prominent in young workers at the age 1–6 days, whether QR or QL, but in the latter their relative amounts are reduced. Isolated workers had high amounts of esters until day 20. Ovarian development in workers requires 7 days, and it approximately matches the disappearance of the esters and an increase in total secretion. Egg-laying was observed among QR workers after the Cph and QL workers, while oocyte-resorption was apparent in QR workers at the pre-Cph, and in isolated workers. The presence of esters in the Dufour's gland seems to be equivalent to low dominance and low reproductive development, since it is negatively correlated with dominance hierarchy and fertility in paired workers. We suggest that Dufour's gland secretion contains information on worker's age, reproductive state, and social status. Its ester constituents might have a communicative role in the colony, since some of the glandular components were also identified on the cuticle of workers. The esters may also relate to the division of labor in the colony, such as discerning foragers from nurses. Finally, ester presence might indicate low reproductive capacity to the queen and other workers, preventing the risks of being mistakenly attacked.

The effect of vegetation on spider diversity in Mt. Meron, Israel

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Biodiversity is threatened constantly and protecting it is becoming a growing need. Therefore, understanding how species diversity is affected by landscape and vegetation is essential. In a landscape where tree patches are dominant and forest canopy closes, diversity of habitats is reduced as open patches become scarce. The research objective is to test how patch type affects spider species diversity and species assemblages. The effect of tree-removal and grazing treatments, which create more open patches in the forest landscape, on spider species diversity will be examined. Spiders are a diverse group of predators, and their use of habitats varies among the different families. For this reason, spiders can serve as indicators of changes in landscape patterns. Spiders can be separated into functional groups based on their foraging strategies: active pursuit hunters, ambushers, and web builders. Vegetation complexity can affect spider foraging behavior and therefore determine the distribution of spiders and spider guilds among habitats. Mt. Meron is the northern study site of a larger long-term ecological research (LTER) project that is conducted along the north–south rainfall gradient in Israel. Mt. Meron is characterized by dense woody vegetation, mainly trees, due to the relatively high precipitation (c. 900 mm annually). In our study, plots were manipulated, creating four treatments: with or without tree-removal and inclusion or exclusion of grazing. We used various methods of sampling (pitfall traps, sweeping, and beating of tree branches) in order to study the distribution of arboreal and terrestrial spider species. We predict that greater a-biotic contrast between open and woody patches will result in increased differences in the spider species assemblage. We will show preliminary results on the effect of patch type (trees and open patches) and the treatments on composition, abundance, and richness of families and the different functional groups of spiders.

Conservation and augmentation of indigenous generalist Phytoseiid predators for control of the citrus rust mite, *Phyllocoptruta oleivora*, in Israel

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The key acarine citrus pest in Israel is the citrus rust mite (CRM), *Phyllocoptruta oleivora*, which is probably the most cosmopolitan citrus pest. In this study we focused on the conservation and augmentation of two indigenous phytoseiids, found to be potential predators of CRM, namely *Amblyseius swirskii* and *Iphiseius degenerans*. In order to identify a chemical suitable for medfly control that is also more selective for these acarine predators we compared the field effects of spinosad to malathion, and found the former to be more selective to *A. swirskii* than the latter. Field augmentation trials with *A. swirskii* and *I. degenerans* yielded significantly higher levels of predators in some of the trials, but had no effect on CRM populations. In unsprayed groves where CRM is under control these predators subsist on a diet composed of alternate food sources, such as other mites, small insect prey, pollen, honeydew, and various fungi. We thus believe that habitat management and conservation should become part and parcel of an indigenous predator augmentative program.

Spider families along a rainfall gradient in Israel

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Spiders are predators that use a variety of methods to capture their prey. They can be divided into guilds based on their foraging strategy: active pursuit hunters, ambushers, and web builders. In addition, they can be differentiated into diurnal and nocturnal species. Each of these guilds has different needs in term of habitat features. Vegetation architectural complexity is expected to influence the guild structure in a given habitat as well as the species composition and relative abundance of each guild. We investigated effects of vegetation structure on the assemblage of local spider communities. We use the guild concept to analyze biodiversity data from five stations along the rainfall gradient from north to south in Israel: Mt. Meron, Ramat HaNadiv, and 'Adullam in the more mesic range and Lehavim and Avedat in the arid region of Israel. The data are from pitfall traps, shrub beating, and sweeping done in open and woody patches at four treatment types: removal of the dominant shrubs and trees, grazing, grazing and tree/shrub removal, and control (no manipulation). We constructed a guild composition for each site along the rainfall gradient, examined patterns of change in guild composition and abundance in open and woody patches in each plot, and compared guild composition and abundance in the different treatments. We find that (1) the influence of woody patches on spider abundance decreases with increasing rainfall from south to north, (2) active pursuit spiders of the family Gnaphosidae dominate arid and exposed habitat patches in the southern sites, and are replaced by Lycosidae, which dominate humid

and shaded patches in the northern sites, and (3) web building spiders are abundant in disturbed patches (removal/grazing treatments). Our study provides preliminary data on the effect of the main structural elements of the landscape on spider diversity along the rainfall gradient in Israel.

Arthropod study and research at Ramat HaNadiv Park, Israel

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Ramat HaNadiv, situated at the south of Mount Carmel, presents a variety of natural environments. In the past 20 years, the park's in-depth ecological study program has served as a model for ecological research on the Mediterranean area of Israel. Varied habitats, extensive ecological research activity, and a skilled team of researchers make Ramat HaNadiv the ultimate "Field Laboratory" for the formal education system of Israel. The educational program "Researching with Researchers" enables students from all over Israel to participate in actual ecological research being conducted at Ramat HaNadiv. Among the research subjects offered is arthropod research, which enables both students and teachers to participate in ecological research and exposes them to an amazing world of the arthropod phylum and its representatives. Arthropod research is carried out in varied habitats: natural maquis, artificially planted pine trees, and a wheat field, in order to characterize each one and enable comparisons between them. From each of the habitats abiotic data are collected, vegetation transect sampling is carried out, and arthropod data are collected using varied sampling methods: Pitfall traps placed in each habitat, insect net sweeping, beating vegetation, sifting soil and leaf litter. Arthropod data are processed to the level of order, which enables students to study the differences between the arthropods orders. Data analysis indicates the arthropod diversity as influenced by different habitats and human influence on arthropod diversity. Varied habitats, simple research methods, and a large diversity of arthropod species all year round provide students with a good experience in researching and observing arthropods in nature and give them a real acquaintance with the arthropod phylum.

Detection of *Borrelia persica* in populations of the tick, *Ornithodoros tholozani* (Acari: Argasidae)

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Tick-borne relapsing fever (cave fever) is caused by *Borrelia persica* and is transmitted to humans by the soft tick *Ornithodoros tholozani*. During 1980–2007 230 cases were reported in Israel among civilians (8 cases/year). Eighty-six percent were recorded from caves and the rest from ruins or animal burrows. These habitats harbor suitable microclimatic conditions for the ticks, which burrow into the ground or hide in crevices. *Ornithodoros tholozani* feeds on warm-bloodied hosts. The tick is distributed all over Israel except the southern Negev. The distribution of the disease reflects the tick distribution. The reservoir of *B. persica* in Israel is unknown, but transovarial transmission of the bacterium to the tick offspring occurs. Probably in Israel, the tick is both the reservoir and the vector. Ninety-two percent of infected humans are hikers and youth and only 7.5% are professional workers. Polymerase Chain Reaction (PCR) methods were first developed in the Ministry of Health laboratories to amplify *Borrelia* specific sequences from tick samples. After sequencing, three subspecies were identified, all characterized by a gap of 7 amino-acids in

the gene flagellin (flaB). This signature was not found in other *Borrelia* species causing relapsing fever elsewhere in the world. The first survey of 30 caves in Israel was conducted in 2005–2007 using PCR methods to identify infected populations with the bacterium and to determine the infection level. The ticks were trapped by CO_2 attraction into bowls dug into the ground. Fourteen caves (46%) were infested with *O. tholozani*. The number of ticks trapped per cave was between a few to several thousand. Specimens from 8 of the 14 infested caves were tested, of which seven populations were positive for *B. persica*. The level of infection ranged from <2% to 40%. This indicates that a high risk of contracting the disease is associated with exposure to ticks in the caves and requires prevention measures.

The neuroanatomic organization of cells expressing the circadian clock proteins CYCLE and CRYPTOCHROME in the brain of the honeybee, *Apis mellifera*

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Understanding the clock mechanism, which controls behavioral rhythms, requires the identification of the oscillator cells and the understanding of their intracellular and intraneural communication. Previous studies demonstrated that the clock protein, PERIOD (PER), is expressed in the pars lateralis of the honeybee protocerebrum, and the clock neuropeptide PDF (Pigment Dispersing Factor) is expressed in cells in the optic lobes, which send fibers to the central brain. These findings suggest that the honeybee circadian clock is organized differently from that in the fruit fly, *Drosophila melanoganter*, where PER and PDF are expressed in the same cells. The goal of the current research is to better characterize the neuroanatomical organization of the honeybee clock, using antibodies against the clock proteins CRYPTOCHROME (CRY) and CYCLE (CYC). To achieve this goal we developed an antibody against honeybee CRY, and used an antibody that was developed against *D. melanogaster* CYC. We found that CRY is expressed in certain cells in the antennal lobe, which project to the central brain. Double labeling experiments demonstrated that these fibers run in proximity to PDF expressing fibers. In the area of the antennal lobe there are cells that express CYC; these cells also project fibers to the central brain. In some experiments the CYC and CRY antibodies stained cells in the lateral protocerebrum, an area where we previously found PER-expressing cells. In order to examine whether CRY expression oscillates during the day, we tested the staining intensity of forager brains that were sampled at 4-hour intervals for one day. The qualitative analysis suggests that there are differences in the intensity of expression. Our findings suggest that in the honeybee the frontal protocerebrum integrates cells and fibers of the circadian network.

Red and green spider mites of agricultural importance in Israel

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During 2004–6 we found that the green two-spotted spider mite (Acari: Tetranychidae) widespread in apple, peach, almond, and fig orchards all over Israel, is *Tetranychus turkestani* Ugarov

& Nikolskii. It is closely related and very similar, morphologically, molecularly, and damage-wise, to *T. urticae*. Males of both species mate with females of the other, but there is a complete post-zygotic reproductive barrier between the two. Red females (synonym = *Tetranychus cinnabarinus*) are very common in numerous herbaceous host plants, whereas green *T. urticae* are not widespread. In Israel *T. turkestani* is a pest of deciduous fruit trees, also infesting watermelon in the north, being at times sympatric with the common red–*T. urticae*. *T. turkestani* females preferred leaf discs of apple over those of watermelon and *Convolvulus* sp. in the laboratory, and peach leaves over *Solanum nigrum* and cotton. The latter species and *T. urticae*, which is closely related and is also very polyphagous, occur on the same hosts and may thus mate in nature. Aspects of competition between *T. turkestani* and red–*T. urticae* were tested. No competitive exclusion took place when females of both species were given a choice between adjacent leaf discs of watermelon and of apple, at high mite density and host selection remained constant in the presence of the competitor. Oviposition rate, sex ratio, and progeny survival were recorded from conspecific (2 couples) versus heterospecific (2 couples) combinations. Oviposition rate and progeny survival did not differ in the above treatments. However, the progeny of red–*T. urticae* from the heterogeneous combination showed an increased male-biased sex ratio, whereas the *T. turkestani* sex ratio was unaffected. This suggests an asymmetric reproductive interference that can affect the competitive success of the two species in a common habitat.

The effect of colored shading nets on the risk for invasion and establishment of insect pests in pepper

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In recent years colored shading nets have been tested in Israel as crop cover for improving yields. Along these studies we evaluate the effect of these nets on the risk of pest invasion and establishment. The main pests of protected crops in Israel are whiteflies (*Bemisia tabaci*), thrips (*Thrips tabaci* and *Frankliniella occidentalis*), and aphids (*Aphis gossypii* and *Myzus persicae*). These pests cause damage by sucking plants and transmitting viral diseases. These pests are known to be attracted or repelled by various colors. During the spring and summer of 2007 we compared the risk for infestation by these pests in walk-in tunnels (6.0 × 6.0 × 2.5 m) at the Besor experimental station. The tunnels were covered with either black, red, pearl, or yellow 30% shading nets (Chromatinet™ by Polysack Co., Israel). Bell peppers were grown in these tunnels. There were 4 replicates (tunnels) for each colored net which were arranged in a Latin square. Infestation levels of whiteflies were significantly lower (2-fold) under the yellow net compare to the black net. Infestation levels of whiteflies were significantly higher (1.5 fold) under the pearl net compare to the black net. Infestation levels of thrips were significantly higher (1.5 fold) under the yellow net compared to the black net. Infestation levels of aphids were significantly lower (2-fold) under the pearl net compared to the black net. The incidence of an aphid-born viral disease (cucumber mosaic virus) was significantly lower under the pearl net (10-fold) and under the yellow net (3-fold) compared to the black net. Pepper yields were highest under the red net which had no significant effect on the risk of pest infestation.

Effect of gut bacteria on nutritional status and reproductive success of the Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae)

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In the Mediterranean fruit fly (*Ceratitis capitata* Wiedemann, Diptera: Tephritidae), enteric bacteria (Enterobacteriaceae) dominate the bacterial community inhabiting the adult alimentary canal. Our objective was to test the hypothesis that bacteria contribute to fly fitness by enhancing copulatory success and egg production in males and females, respectively. Following eclosion, flies were maintained either on sugar or on a full diet which provided all nutritional needs. Sub-groups from each diet were fed a mixture of antibiotics. We quantified bacteria numbers in the gut, food consumption, longevity, weight gain, lipid and protein levels, oviposition in females, and copulatory success of males in the 4 treatment groups. The antibiotic treatment effectively cleared the gut of bacteria. Feeding on antibiotics did not affect dry weight or the amount of protein stored. Amounts consumed were similar in all treatment groups, with the exception of females feeding on the full diet, who consumed significantly more than counterparts feeding on the full diet with antibiotics. These females also had increased lipid levels. Longevity was prolonged in antibiotic-treated flies fed with sugar, but not when fed the full diet. Females fed on the full diet produced significantly more eggs than females on the sugar diet, but the presence of bacteria did not affect the numbers of eggs produced. However, in the absence of bacteria, oviposition rate of nutritionally stressed females was significantly accelerated. The antibiotic treatment was not correlated with a mating advantage in sugar-fed males. Conversely, in the males fed a full diet it was significantly associated with a shorter latency to mate. We conclude that removal of bacteria affected measurable physiological and behavioral parameters related to fitness, and that the nature of the association between the fly and its gut bacteria range from mutualistic to parasitic, depending on the diet.

Population dynamics of the banana aphid (Hemiptera: Aphididae), and its insect associates in the coastal plain banana plantations of Israel

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Pentalonia nigronervosa (Coquerel) is a stenophagous species on banana *Musa* spp. The aphid is a major pest of banana in Israel, causing decline in the crop yield due to distortions of plant growth and sooty mould cover. The seasonal history of the aphid was studied in two banana growing conditions (open and netted plantations). The population density was determined by examining the aphid colonies and by setting up yellow sticky traps from August 2005 and August 2007. Aphid population annual trend was similar under open and netted banana plantation. The aphid population decreased from February to April, and during August, while from April and June, and October to December, the population steeply increased. These fluctuations are likely to be explained by the effect of temperature on the aphid. Aphids grown under a number of controlled temperature regimes in the laboratory, cease to develop at >30 °C and <10 °C. Based on laboratory observation

it seems that the optimal (the highest reproduction rate in the shortest time) temperature for the development of the aphid is 28–25 °C. Ten ant species were found in association with the banana aphid in the coastal plain plantations; two or more ant species were usually found in a colony. The most common attendant was the ant *Paratrechina longicornis*. Several species of natural enemies, predators and parasitoids, were found in the aphid populations under natural conditions, while the most abundant were species of the family Coccinellidae. In general, these enemies are present in the plantations especially when the aphid population grows; however, their influence on the aphid population was not examined in this study. No doubt their presence is of importance in the plantation.

Differential distribution and expression of PBAN/Pyrokinin G-protein coupled receptors (GPCRs) in *Helicoverpa* spp. (Lepidoptera: Noctuidae)

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Moths are one of the major groups of agricultural pests. Moth sexual communication relies on pheromones: the female moth producing and releasing the sexual signal and the male moth receiving it. Pheromone biosynthesis activating neuropeptide (PBAN) activates pheromone production in the pheromone gland of the female moth *Helicoverpa* spp. The PBAN/Pyrokinin peptide family is characterized by a common amino acid sequence motif FXPRLamide in the C terminus. Without this motif the female moth would not produce sex pheromone. For its activity, PBAN has to bind to its receptor, which is located in the pheromone gland membrane cells. This receptor belongs to the G-protein coupled receptor family (GPCRs) and is classified with the vertebrates subfamily neuromedin U. An intensive research concerning this receptor family is conducted in the pharmaceutical industry, since they are involved in different human diseases. In this research, the distribution and the differential expression of the receptor gene in different tissues of *Helicoverpa* spp. was investigated, in order to locate PBAN receptors and/or new PBAN-like receptors with additional roles in the moth. This research was done using advance biochemistry and molecular biology tools, and indicated that the PBAN receptor is localized in the neural tissues as well. This research also shows that the PBAN receptor is present in the male tissue which is homologous to the pheromone gland. This finding is surprising since previously, no activity and/or receptor-ligand protein complex was identified. These results raise many questions concerning the evolutionary role of the PBAN/Pyrokinin receptors of the GPCR family. In addition, information provided from this research can help in designing antagonists, which will disrupt the sexual communication and by doing so will cause a reduction in the specific pest population.

Chemical ecology of bark beetles (Coleoptera: Curculionidae) in western USA and Europe

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Bark beetles in the family Curculionidae (formerly Scolytidae) are important .pests of forest trees, especially conifers. Two of the most important species in California are the western pine beetle, *Dendroctonus brevicomis*, and the 5-spined ips engraver, *Ips paraconfusus*. These species compete for the relatively thin bark areas of ponderosa pine, the most prevalent conifer of California

and nearby states. Both bark beetle species have evolved olfactory mechanisms for reducing interspecific competition by avoiding pheromones of the opposite species. Both species also regulate intraspecific competition by avoiding their own aggregation pheromones at high concentrations or by avoiding repellent pheromones. Biosynthesis of these pheromones by beetles from monoterpene precursors in the host tree became a paradigm, but subsequent research has modified this view for some but not all of the semiochemicals. In Europe, some of the same mechanisms for avoiding competition were found in beetles attacking Norway spruce, *Ips typographus* and *Pityogenes chalcographus*. The paradigm that all "aggressive" pest bark beetles colonizing conifers must utilize an aggregation pheromone was questioned for the pine shoot bark beetle, *Tomicus piniperda*. This beetle colonizes Scotch pine similar to other bark beetles but finds its host tree by attraction to monoterpenes rather than by an aggregation pheromone. However, a sibling species, *T. minor*, has an aggregation pheromone in addition to a weak attraction to host monoterpenes. The paradigm that all bark beetles find their host tree simply by an attraction to pheromones and/or host volatiles is not supported by studies with *P. bidentatus*. This species does have an aggregation pheromone but host finding effectiveness is probably enhanced by avoidance of volatiles from commonly occurring non-host trees (Norway spruce, oak, ash, and birch). The beetle prefers aged/diseased pine branches so it also avoids host monoterpenes indicative of a healthy/vigorous host that is less suitable for reproduction.

Studies on thrips migratory flight in Israel

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In recent years we used 3.0 m high sticky blue pole traps to determine the annual and daily variations in the migratory flight of *Thrips tabaci* and *Frankliniella occidentalis*. About 90% of the thrips were trapped when the wind speed was below 10 km/h, and the prevailing winds were westerly. The highest number of thrips was trapped on the eastern sector of the poles (40–50%) and the lowest on the western sector (10–20%). When we used similar traps that were mounted on wind vane most thrips (75%) were caught on the leeward side. Thus, it appears that thrips fly upwind during most of their migration. In an open area, about 70% of the thrips were caught below the height of 1.0 m above ground. We investigated if this distribution is the result of a natural gradient or a secondary flight toward the trap after thrips landing at the vicinity of the pole. The bases of the pole traps were placed on a 2.0 × 2.0 m colored (white, green and blue) boards. Pairs of poles with similar colored bases were placed in an open field and one base was covered with sticky glue. In the pairs with white or green bases there were no differences in the numbers of thrips trapped on the poles below 1.0 m above ground. In the pairs with blue bases there were no differences in the numbers of thrips trapped on the poles at 1.0 m above ground. However, significantly lower numbers of thrips (20%) were trapped on the poles with blue sticky base at 0.3 m above ground. Thus, it appears that thrips fly directly toward the trap during their migration. The fact that most thrips were trapped below 1.0 m above ground probably reflects their vertical concentration gradient in the air.

The effect of colored nets on efficiency of the predatory mite, *Amblyseius swirskii*, in sweet pepper in Israel

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Sweet pepper is an important crop in Israel, with about 2250 ha in production. About a quarter of that area is grown under shade netting in the early autumn and late spring to reduce temperatures and prevent sun-burning of fruit. Research has shown that the use of colored shade nets can affect plant growth and yield, and the intensity of fungal disease. However, the effect of colored shade netting on arthropod pest and predator populations was virtually unknown. The phytoseiid predatory mite, *Amblyseius swirskii* Athias-Henriot, is a type III predator able to feed on pollen and small arthropods. Originally found in citrus groves in Israel, laboratory research in Europe has demonstrated its ability as an effective biological control agent against the key pests *Bemisia tabaci* and *Frankliniella occidentalis*. Recent work in Israel has demonstrated its ability to also control the broad mite, *Polyphagotarsonemus latus*, a major pest on many crops in open fields and greenhouses world-wide. We evaluated the effect of 5 different colored nets on pest (whitefly and broad mite) and predator (*A. swirskii*) populations on sweet pepper plants at the Gilat Research Center by sampling whole plants weekly. Significantly fewer predators were found on plants under yellow nets, whereas more pests were found on plants under these same nets. Plants grown under black shade nets had the largest predator population and lowest pest population. The ramifications of these results will be discussed in the conference.

Integrated means for the control of phlebotomine sand flies (Diptera: Psychodidae) in and around human habitation in Israel

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Sand flies can transmit a variety of viral diseases as well as parasites such as *Leishmania*, which causes cutaneous leishmaniasis. Apart from being a health hazard, sand flies' bites can constitute a serious nuisance to those sensitive to their saliva. Control of phlebotomine sand flies is problematic since the breeding sites of their immature stages are unknown and/or inaccessible. We are developing and testing several approaches for controlling biting female sand flies by: (1) Construction of insecticide-treated upright physical barriers. (2) Constructing external wall sticky shelves as horizontal barriers. (3) Mass scale trapping of sand flies using commercial traps. Results from 2005–6 indicate a significant reduction (>90%, $p < 0.01$) in sand fly abundance in a small scale experiment using a 50 mesh net barrier (SprayNet50®, Meteor Inc., Petah Tikva) treated with insecticide. External wall shelves exhibited >50% reduction in sand fly numbers entering treated houses ($p < 0.05$). Comparison between three types of commercial mosquito traps showed significant superiority of the updraft type inverted CDC traps ($p < 0.01$), baited with CO_2. Currently we are testing the upright barrier in the town of Ma'ale Adumim in order to assess its efficacy in large scale application. We continue the testing of additional trap types in order to attain long term continuous trapping. It is anticipated that acceptable levels of control can be achieved using integrated strategies, coupled with personal protection.

The beginning of entomological research in Israel (1900-1930)

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Malaria was the most important disease in Israel until early 20th century. Thus, the first significant entomological research was dedicated to the disease. Dr. John Cropper, a British missionary physician, was a pioneer in the field. Two years after Grassi's discovery on the role of *Anopheles* as a vector of human malaria, Dr. Cropper monitored *Anopheles* population in Palestine and found it to correlate with malaria cases (1902). Malaria research was intensified with the establishing of the Malaria Research Unit by Dr. I.J. Kligler who was assisted by G. Mer, Z. Saliternic, and others. Kligler published about 150 papers dealing with malaria and its vectors. His book, *Epidemiology and Control of Malaria in Palestine* (1930), became a classic in the field. Dr. S. Adler and his assistant O. Theodor investigated Leishmania and first published in 1925. During the years the two became world leaders on Leishmania and its vectors. The year 1922 can be considered as the beginning of organized agricultural entomological research: (1) The Plant Protection Department was established by the British Mandatory Government with Dr. P.A. Buxton as the chief entomologist. (2) The Agricultural Experimental Station was established by the Palestine Zionist Executive with Dr. F.S. Bodenheimer as the head of the Entomology Department. In fact it was a one man department, later assisted by Z. Klein (Avidov). Buxton as well as Bodenheimer realized that their first task is to catalogue the pests of the region. Already in 1924, Buxton reported on 40 pests, while Bodenheimer published a list of 400 pests and their bionomics in 1930. During the 1920s he published several papers on scale insects and the Mediterranean fruit fly. All together he published 450 papers and books, emphasizing the ecological approach in which he became a world authority.

Interaction of the mango bud mite, *Aceria mangiferae*, with *Fusarium mangiferae*, the causal agent of mango malformation disease

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It has been suggested in the literature that the mango bud mite, *Aceria mangiferae*, plays an important role in the epidemiology of mango malformation caused by *Fusarium mangiferae*. In a previous study we demonstrated that the mango bud mite is able to carry *F. mangiferae* conidia on its body and transfer them into the penetration site, the apical bud. The current work was designed to study the role of the mites in the infection and dissemination stages. To determine whether the mango bud mite contributes to the penetration stage, potted mango plants were inoculated, in two following years, with Green fluorescent protein (GFP)-marked conidia in two treatments with or without the presence of bud mites. Both frequency and severity of infection were significantly higher in the buds inoculated in combination with the bud mites then in the buds inoculated without the presence of mites. (Frequency: 79 % vs. 49% infected buds; Severity: 40% vs. 14% infected scales per infected bud, respectively). In addition, in order to demonstrate the proximity of similar niches within the bud, apical buds from that experiment were sampled for Scanning Electron Microscopy (SEM) and confocal microscope observations. Mango bud mites were observed in the vicinity of the pathogen's hyphae and conidia. In order to determine the role of the

bud mite in conidial dissemination and possible association between windborne bud mites and windborne conidia, spore and mite traps were placed in a diseased orchard. No windborne bud mites bearing conidia were found on the traps, although high numbers of windborne conidia were trapped. These results suggest that the mango bud mite can improve fungal penetration into the host but apparently the bud mites do not play a role in aerial dissemination of conidia.

The effect of protein nutrition on the survival of sterile male Mediterranean fruit flies

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The Mediterranean Fruit Fly *Ceratitis capitata* (Wied.) (Medfly) is a worldwide highly destructive pest. In recent years, the need for new environmentally friendly methods for Medfly control, as an alternative to chemical sprays (mainly organophosphorus), is growing. One of these alternatives is the Sterile Insect Technique (SIT). SIT efficiency depends on the ability of released males to compete with local wild males. Unfortunately, the sterile, factory-produced males are weaker then the wild ones, hence repeated releases are required. Nutrient manipulations, such as protein supplements, have proved effective in promoting sexual activity of sterile Medfly males but are suspected in harming their ability to survive in the field. Therefore, the first goal of this research was to evaluate survival of sterile flies in comparison with wild flies. The second goal was to determine whether a protein supplement given to the sterile adult flies affects their survival. Sterile adult male flies (Viena-8) were fed on two different diets: sweet agar (containing water and sugar only), and sweet agar + protein supplement (hydrolyzed yeast mixed with sugar). Survival was evaluated after 4 days of feeding, in laboratory conditions, in field enclosure, and in an orchard. Results indicate very poor survival of the sterile males in comparison to wild males, in both lab and field enclosure conditions. After 72 hours of starvation in lab conditions 90% of wild flies have survived compared to only 15% of sterile flies. The addition of protein to the diet of the sterile males had no negative effect on their survival, neither in semi-field conditions of screen house, or in the orchard. This study, along with others, supports providing protein supplements to SIT adults. Such supplements could improve sexual performance without affecting the survival of the released flies.

An update of the small sterile insect technique projects in Israel

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Today, two Sterile Insect Technique (SIT) projects are carried out to control the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) in commercial fruit groves in Israel. The first is in the semi-arid plain of the west of the Negev desert, in nine clusters of orchards. Its total area is 9,300 dunam and it includes two settlements, Kibbutz Gevulot and Kibbutz Ze'elim. The second is an expansion of the former and smaller "Batra" project, carried out over a total area of 9,000 dunam. It includes all the fruit groves at the foot of the Golan along the northeast coast of the Sea of Galilee and the two villages, Ramot and Ma'ale Gamla. The fruit groves in the project consist mainly of mango (75%) and citrus (20%), including pomegranate, apricot, litchi, guava,

and grapes. In both projects sterile male flies are ground released, twice weekly, at rates of 300 to 350 flies/dunam/ week. A network system of Jackson and Tephri traps for male and female flies, respectively, indicates the level and trends in the wild population and the condition of the released flies. Fruit inspection and sampling indicates the presence of fertile flies and sanitation survey indicates the amount of neglected fruit which is an available, yet uncontrolled host. Outbreaks are treated with baited insecticide applications, and bad sanitation is treated by a special fruit stripping. The results of the two projects are encouraging. Two seasons had terminated without Medfly damages. The wild populations were lower in the project area than in the conventionally treated control groves. The intensive sanitation efforts reduced the fly's infestation in the post-seasonal leftover fruit, and the number of bait spray applications was lower in the project area than in the control. Updated results will be shown during the symposium.

Insect–plant relationships, parasitoids and insect pest management

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There is an integral and tight relationship between the basic sciences of insect physiology and ecology and their sub-disciplines of behavior, behavioral ecology, and sociobiology. The physiological and ecological constraints dictate behavioral patterns but these, in turn, enable activities which, in the long run bring about physiological and ecological changes yielding to evolutionary pressures. In the lecture, examples will be presented on behavioral studies and observations demonstrating the relevance and importance of behavioral studies to the understanding of ecological systems and to the implementation of sustainable Insect Pest Mananagement (IPM). The examples include host size selection, insect attraction behavior in relation to environmental stimuli, differential oviposition behaviors in the tamarisk infesting case-bearing Chrysomelid, *Cryptocephalus sinaita*, and the behavioral consequences of habitat fragmentation. The far reaching and popular behavioral studies enabled better understanding of numerous ecological phenomena. They have also exposed us to weaknesses in both theory and practice in the study of insect behavior. We still do not understand the meaning and limits of bet hedging and its applicability in benefitting the individual. The changes in individual behavior when it moves from acting alone to acting in a group are also poorly understood, and we are unable to relate phenomena occurring in minute insect populations to large ones or the varying reaction of insects to changes in food web complexity (including indirect competition).

The immune system and behavioral patterns in the Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae)

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Insects have a simple immune system, protecting them against microorganisms and parasites. Among its humeral components is the enzyme phenoloxidase (PO). PO is crucial in insects for melanin production. In the immune system, PO activates immune processes and melanizes encapsulating hemocytes. In many insects, PO is a known index of the immune system state when manipulating physiological and behavioral parameters. We hypothesized that in the Mediterranean fruit fly *Ceratitis capitata* there is a connection between the immune system and fitness, and that age and nutrition affect the levels of PO. Three experiments were conducted: (1) Levels of

PO were measured after adult emergence and a week later. Older flies had higher levels of PO. (2) Three diets were given: fig, sugar, and sugar plus protein. Flies that ate fig had higher levels of PO and lower weight than flies on the other diets. Overall, females had higher levels of PO than males. Furthermore, a significant interaction was found between gender and diet. (3) Males competed for copulations. Among those who succeed in copulating, those with lower levels of PO started mating sooner. Copulating females had higher levels of PO than females who did not copulate. The change in PO levels after a week probably reflects the normal maturation of the immune system. The fig may support more pathogens than the other diets, eliciting a strong immune response. Furthermore, there may be different resource management strategies in males and females. Finally, immune status affects (in manners we do not yet understand) copulatory success of males and receptivity of females. In conclusion, PO is a good indicator for the immune system and is significantly associated with age, nutrition, and mating success.

Preliminary laboratory tests for controlling populations of the desert locust, *Schistocerca gregaria,* in bio-organic crops

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The desert locust, *Schistocerca gregaria*, has been a pest since the beginning of growing cultivated plants. Israel is situated in a region where locust invasions are common. At the end of 2004, swarms of pink, immature desert locusts migrated from Egypt to southern Israel, near Eilat. The treatment proposed by Plant Protection and Inspection Services officials was very effective, but there was less success in bio-organic fields. Therefore, a search for chemicals to be used on organic crops against this pest was initiated. First, a population of desert locusts was reared in the laboratory, and screening for suitable insecticides was performed. We found that the combination of two plant extracts, *Melaleuca alternifolia* and *Sophora japonica*, gave good results in the laboratory.

Correlation between tomato yellow leaf curl virus transmission efficacy and symbiotic bacteria in the sweet potato whitefly, *Bemisia tabaci*

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The sweet potato whitefly *Bemisia tabaci* (Gennadius) is an exceedingly polyphagous pest. Plant viruses transmitted by *B. tabaci* are probably the most devastating damage inflicted by that pest. *B. tabaci* is considered as a species complex composed of more than 20 biotypes that differ from each other genetically and biologically. Two biotypes have been reported in Israel: B and Q. The former has higher fecundity and competitive abilities, vs. the greater degree of pesticide resistance exhibited by the latter. As other phloem feeders, *B. tabaci* harbor bacterial symbionts: *Portiera aleyrodidarum*, an obligatory primary symbiont, and a diverse array of facultative secondary symbionts such as *Rickettsia, Hamiltonella, Wolbachia,* and *Arsenophonus*. The secondary symbionts community correlates with biotype; while *Hamiltonella* is harbored only in the B biotype,

Wolbachia and *Arsenophonus* are found only in the Q biotype. The association found between whitefly biotypes and secondary symbionts suggests a possible contribution of these bacteria to host characteristics such as insecticide resistance, host range, virus transmission and speciation. The best studied system of whitefly–virus interactions is that of the *B. tabaci*–tomato yellow leaf curl virus (TYLCV). It has been previously shown that virus transmission is directly influenced by a GroEL protein produced by *B. tabaci* symbionts. We cloned GroEL genes produced by *B. tabaci* symbionts, from the B and Q biotypes, and studied the *in vivo* and *in vitro* association between virus transmission capabilities and symbiont contents.

Interactions between a key pest of Liliaceae, the bulb mite, *Rhizoglyphus robini*, and soil fungi

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The bulb mite *Rhizoglyphus robini* (Acaridae: Astigmata) is a soil pest of Liliaceae in Israel. Severe damage to underground plant parts is associated with high populations of the mite and different fungal pathogens. Our goals were (1) to characterize the major fungal pathogens, (2) to examine the influence of the fungi on the mites, and (3) to study the interaction between the mites and the fungi. The pathogenicity of different fungal species and strains was evaluated on onion seedlings. Four levels of mite populations were assessed using the same methodology. Attraction of the mites to the different fungi was compared without the host plant. The interaction between the mite, fungus, and onion seedlings was studied by observing the attraction of the mites to infested onion seedlings with a weak pathogenic fungus and by measuring onion seedling damage with and without the mites and the fungus. Different levels of pathogenicity between fungal species, and between sub-species of the same fungus, were observed. Mites were attracted to most tested fungal species and strains but the degree of attraction varied and was not related to pathogenicity. The combination of the relatively weak pathogenic fungus *F. moniliforme* (purple strain) and mites was more severe to onion seedlings than each factor alone. Currently *R. robini* management is based on highly toxic insecticides. Our results suggest that fungal control could be a more effective and environmentally friendly method instead of mite control to prevent the damage inflicted by these two causal agents.

Bioavailability of PK/PBAN derived agonistic and antagonistic peptides in *Heliothis peltigera*

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The pyrokinin (PK)/pheromone biosynthesis activation neuropeptide (PBAN) family is a multifunctional family of peptides that plays a major role in the physiology of insects. In the past few years our laboratory focused on a detailed characterization of the structure activity relationship (SAR) of this family using a novel approach for rational design (Altstein et al., 1999, J. Biol. Chem. 274, 17573–17579). Diverse libraries and peptides were designed and synthesized

containing linear and cyclic peptides with different modifications of the active signature core (FSPRL-amide) of the PK/PBAN family. The peptides were tested for their agonistic and antagonistic activity, in *Heliothis peltigera*, by means of the pheromonotropic assay (Gazit et al., 1990, Insect Biochem. 20, 853-858) and a few pure agonists and antagonists (e.g., peptides capable of inhibiting the pheromonotropic activity of exogenously administered PBAN or other stimulatory PK/PBAN peptides) were found. In order to determine whether the peptides are bioavailable and to determine the structural requirements for bioavailability — the most potent agonists and antagonists were tested for their stimulatory and inhibitory activity by means of topical application. Agonistic peptides were tested for their ability to evoke pheromonotropic activity during photophase; antagonistic peptides were tested for their inhibitory potency during photophase (where sex pheromone biosynthesis was evoked by topically applied synthetic PK/PBAN peptides), and during scotophase on sex pheromone biosynthesis evoked by the endogenous mechanism. Peptides were tested at different concentrations, in different solvents and times of application. The data revealed high bioavailability of some of the linear and BBC peptides as indicated by their ability to stimulate sex pheromone biosynthesis during photophase and their high efficiency to inhibit sex pheromone biosynthesis evoked by synthetic peptides as well as the endogenous mechanisms.

Diversity patterns and pollination services by bees in natural and agricultural habitats in the Araba/Arava Rift Valley

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Bees provide vital pollination services to crops and wild plants. Modern agriculture relies on a few commercially grown bee species for pollination, mainly honey bees and bumblebees, even though wild bees can provide significant pollination services. The reliance on honey bees as the main agriculture pollinator is inherently risky especially in light of sharp declines in their colonies across the world, including Israel. Furthermore, honey bees can negatively affect the wild bee fauna. Pollination services provided by wild bees and the effects of land-use practices on them have not been investigated yet in Israel. These issues are especially critical in arid ecosystems, sensitive to anthropogenic disturbance. In this study we investigated habitat use by wild bees along their activity season and their contribution to crop pollination in the Araba/Arava Rift Valley. The research was conducted across the Jordanian–Israeli border and included four main habitats: open landscapes, gardens in settlements, and watermelon grown in open fields or under cover (plastic tunnels with large openings). In each habitat type we established 4 2500 m^2 plots. Bees and plants were sampled 6 times between March–July. Honey bees were sampled in all habitats and were dominant in gardens and agriculture habitats. Bumblebees (workers and queens) were sampled in gardens. Wild bees were sampled mainly in open landscapes, and toward the end of the season also in gardens and agriculture habitats. Gardens provided a relatively constant amount and diversity

of floral resources, while in the other habitats floral resources gradually declined along the season. Gardens may provide important foraging resources for bees at times when they are scarce. This constant augmentation of foraging source may affect the native bee community. Despite the fact that wild bees can be efficient agriculture pollinators, their contribution to watermelon pollination in our system is limited.

The role of bacterial symbionts in biological control of insect pests

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Associations of arthropods with inherited, intracellular bacterial symbionts are very common. While mutualist, obligate symbionts have long been known to supply nutritional supplements to their hosts, we are just beginning to characterize the incredible diversity and function of many facultative (= secondary) symbiont relationships. Secondary symbionts may mediate important ecological interactions, manipulate reproduction, and be agents of swift evolutionary change in their host populations. My laboratory studies the role of secondary symbionts in biological control — in parasitoids, herbivores, and in the parasitoid–host relationship. Parasitoid wasps are frequently inhabited by symbionts that manipulate wasp reproduction in ways that enhance their own transmission. Both mating incompatibilities (cytoplasmic incompatibility, or CI) and parthenogenesis-induction are common phenotypes. We have been studying *Cardinium*, a bacterial symbiont that is common in whitefly parasitoids in the genus *Encarsia*. In *Encarsia*, *Cardinium* strains cause parthenogenesis and CI. Recently, we have been testing the theory of how a CI symbiont spreads in a population of *Encarsia pergandiella*, a parasitoid of the sweetpotato whitefly, *Bemisia tabaci*. In sweetpotato whiteflies, in collaboration with Einat Zchori-Fein, we have been investigating a Rickettsia symbiont that shows remarkably fast spread in the Southwestern United States. Our preliminary data suggest that this symbiont is detrimental to some parasitoids that develop on the infected whitefly host. We are now trying to determine the mechanism of *Rickettsia* spread, and the symbionts' effects on whiteflies and parasitoids. In a third project, we are studying secondary symbionts of pea aphids that confer resistance to aphid parasitoids. We find that different strains of one bacterial symbiont in particular, *Hamiltonella*, confer different levels of resistance, from about 20% to virtually 100%. Also symbionts, not aphid genotype, explain most of the variation in resistance. Aphid symbionts may thus sometimes explain variation in effectiveness of biological control. Historically, biological control has always been a very knowledge-intensive discipline, where an understanding of the basic biology of pest and natural enemy may make the difference between failure or success. Microbial symbionts have been cryptic factors influencing the biology and ecology of pests and natural enemies, and we believe that understanding their role will increase the efficacy of biological control.