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Overviews and trends on stored product protection

Implementation of methyl bromide alternatives in Poland

Ignatowicz S., Olejarski P...... 3-7

Abstract: Methyl bromide (MB), a powerful ozone-depleting substance, was phased-out in Poland in 2005. MB had been widely used in Poland, and it cannot be replaced by one alternative, but various methods and means have to be used. The following MB alternatives are currently used or may soon be used in Poland: (a) phosphine, (b) contact insecticides, (c) heat, (d) high pressure and CO₂, and (e) Integrated Pest Management (IPM). Future perspectives include: ECO₂FUME, PH₃ mixtures with CO₂ or N₂, sulfuryl fluoride, irradiation and cooling to sub zero temperatures.

Restrictions to the use of fumigants and opportunities for substitution with botanicals and modified atmospheres

Navarro S., Donahaye, E. 9-22

Abstract: Concerns over the adverse effects of fumigant residues in food and the environment have led regulatory agencies to take actions by imposing strict limitations on fumigant registration. Of the long list of fumigants two decades ago, very few remain today. MB has a relatively quick killing effect on insects, but - because of its contribution to stratospheric ozone depletion - has been phased out in developed countries since 2005, and in developing countries phase out will take place by 2015. In contrast, phosphine remains popular, even though insects have developed resistance to it. These restrictions on the use of fumigants have posed new global challenges to the food industry, and have resulted in efforts to register new fumigants, and in the development of new technologies as alternative control methods.

Among the newly considered fumigants are sulfuryl fluoride, carbonyl sulphide, propylene oxide, methyl iodide, ozone, ethyl formate, and hydrogen cyanide. Sulfuryl fluoride seems to emerge as a promising candidate fumigant for disinfecting stored food commodities, food-processing facilities and as a quarantine fumigant. Other registered fumigants suffer from the limitation that they may be useful for treating a particular type of commodity or for application in a specific situation only. The potential use of volatiles of botanical origin shows promise but requires both commercial scale trials and registration procedure before they can be employed in practice. Among the new gaseous application technologies that have successfully replaced fumigants are the manipulation of modified atmospheres (MAs) alone or at high temperatures, and high pressure carbon dioxide that needs to be further explored for specific applications. A recent development is the use of MAs in a low-pressure environment. These niche applications of MAs that have resulted in very promising application treatments with market acceptability, should serve as models for global challenges for new application methods.

Anobium punctatum (Coleoptera: Anobiidae), a new pest of books in Israel

Wilamowski A., Schnur H., Kessler I., Navarro S. 23-28

Abstract: In 2004, *Anobium punctatum* was found to have caused a very serious infestation of books stored in one of the largest libraries in Israel containing approximately 5 million books. It was estimated that around 7% of the books were infested or suspected of being infested and required treatment. The damage caused is characteristic to the lifestyle of *A. punctatum*. This

species is distributed in temperate climates, is common in Europe and North America and is considered to be the main pest of dry wood and dry wood products. It was recorded in Israel in the past from imported wood infested with larvae and in 1995. Several books were found infested with this species in one of the religious libraries in Israel. However, the damage was negligible and the population did not become established nor did it spread to other libraries in Israel. It is assumed that the dryness and high temperatures in Israel prevent the egg-laying activity of the adult beetles in nature. It is assumed that in the case of the severe library infestation mentioned above, the first infestation foci were of books brought from abroad. The level of infestation and damage and the long period of development indicated that the infestation had developed over many years. Two control operations are necessary in order to exterminate the beetles: fogging of the library to kill the adults and treatment of the books to kill the larvae and pupae. Three methods were considered: fumigation using methyl bromide; anoxia or freezing to -30°C , the last of which has already been implemented.

Potential of parasitic protozoans in biological control of stored products pests

Lipa J.J. 29
Abstract only

Biology and ecology of stored product pests

Description and putative function of the antennal sensilla of *Habrobracon hebetor* (Say)

(Hymenoptera: Braconidae)

Dweck H.K., Gadallah N.S. 33

Abstract only

Plodia interpunctella (Hübner) mating suppression with an emulsive pheromone preparation - laboratory experiments

Komorowska-Kulik, J., Celmer-Warda K., Bombinska D., Al Amin I. 35-39

Abstract: Three experiments were conducted in unventilated laboratory rooms (125 m^3 - first (I) experiment, and 168 m^3 - second (II) and third (III) exp.). Walls of the rooms, except ceilings and floors, were sprayed with the pheromone emulsive formulation of (Z9,E12)-tetradeca-9,12-dien-1-ol acetate (Z9E12-14Ac). Amounts of Z9E12-14Ac sprayed on the walls were: $32\text{ mg}/80\text{ m}^2$ (I exp.) and $24\text{ mg}/120\text{ m}^2$ (II and III exp.). The residual amounts of the pheromone remaining on the walls were checked after each 7 day. Each experiment consisted of two 7-day tests and a 7-day interval between them. An attractant for *P. interpunctella* female (consisting of nuts, chocolate and a mat of silken webbing produced by larvae) was exposed in the room, and 20 to 50 pairs of virgin 2-3 day adults of *P. interpunctella* were released at the beginning of each test. After 7 days the attractant was collected and kept in a rearing room to breed adults from the eggs laid on them. Control tests were performed in the same manner but without using the pheromone. The bred *P. interpunctella* moths were counted. Reductions of the moth populations were 95-75 % in comparison with the control tests.

Attraction of *Sitophilus zeamais* Motschulsky to different types of cereal pasta

Trematerra P., Visini G., Romagnoli L., Palladino A., Mancini E. 41-48

Abstract: Pasta factories use flour, a raw material obtained principally from hard wheat but also from other cereals (e.g. barley, corn, kamut, rice, spelt) which come directly from the mill. Flours are the main source of reproduction and diffusion of pests because of the structure of the mill, the possible use of infested cereals and large quantity of dust always present. As a result *Ephestia kuehniella* Z., *Lasioderma serricorne* (F.), *Oryzaephilus* spp., *Plodia interpunctella* (Hb.), *Rhyzopertha dominica* (F.), *Sitophilus* spp., *Stegobium paniceum* (L.), and *Tribolium* spp. present in warehouses, silos and in mills are carried into pasta factories where they can multiply. In many Italian pasta factories new technics and Integrated Pest Management have been suggested for the prevention and control of pests. Despite these provisions, the problem of pest attacks by *Lasioderma*, *Plodia*, *Rhyzopertha*, *Sitophilus* and *Stegobium* in pasta factories, from packaging to the consumer, remains unsolved because of specific aspects of used packaging and the negligence in warehouses and stores in addition to the long average shelf-life of the product. In that context, in our study, we compared attraction of *Sitophilus zeamais* Motschulsky to 8 different types of Italian cereal pasta produced with: barley, buckweath, durum wheat, 5 cereals (a mixture of durum wheat, barley, spelt, oat, and rye), kamut, corn, rice, and spelt. The results obtained in

olfactometer tests demonstrated that *S. zeamais* adults revealed preferences in decreasing order for pasta realized with corn, buckweath, durum wheat, rice, barley, kamut, spelt, and 5 cereals.

Bacterial flora of *Lasioderma serricornne* (F.) (Coleoptera: Anobiidae) from several tobacco stores in Turkey

Yaman M., Aslan I., Görmez A., Ertürk Ö. 49-52

Abstract: In the present study, bacterial flora of *Lasioderma serricornne* from tobacco stores in eight localities in Turkey were studied. Totally, 15 different bacteria were isolated and identified on the basis of fatty acid methyl ester (FAMES) analysis and carbon utilization profile by using Microbial Identification and Biolog Microplate Systems. Most isolated bacteria were from the genus *Bacillus*. Nine of 15 identified bacteria were from the genus *Bacillus*. Identified bacteria are

Bacillus cereus, *B. megaterium*, *B. thuringiensis*, *B. subtilis*, *B. pumilus*, *B. atrophaeus*, *B. badius*, *B. clausi*, *B. parabrevis*, *Brevibacterium liquefaciens*, *Brevibacillus parabrevis*, *Micrococcus luteus*, *Pseudomonas syringae*, *Staphylococcus gallinarum* and *Salmonella typhimurium*. *B. cereus*, *B. megaterium* and *B. thuringiensis* were most common found bacteria in the investigated localities. *B. megaterium* were isolated from six of the eight investigated tobacco stores, *B. thuringiensis* from five and *B. cereus* from 4 stores.

Studies on the feeding, reproduction and development of *Cheletomorpha lepidopterorum* (Schaw) (Prostigmata: Cheyletidae) on various food sources

Yassin E.M.A., Sallam G.M.E. Ibrahim S.A. 53-62

Abstract: *Cheletomorpha lepidopterorum* as a biological control agent used against different mite pests was reared individually on immature stages of different mite diets belonging to suborder Astigmata (*Tyrophagus putrescentiae*, *Lepidoglyphus destructor*, *Rhizoglyphus echinopus* and *Caloglyphus betae*) at different temperatures (20, 25 and 30°C) and (70 – 80 % R.H.). It was noticed that the predator female passed through two nymphal stages (protonymph and deutonymph), while males have only one nymphal stage. The predatory mite developed faster when reared at 30°C than 20°C. When four astigmatid mites were compared as food, *Cheletomorpha lepidopterorum* showed a higher fertility and lived longer on *T. putrescentiae* as food than on other diets. Cannibalism was usually noticed when the preys were absent or scarce.

Suitability of species as food for mould mite (*Tyrophagus putrescentiae* (Selm))

Czajkowska B. 63

Abstract only

Insect detection, monitoring, trapping, pheromones and mating disruption

Comparison of methods for sampling psocids in stored wheat

Throne J.E., Opit G.P., Flinn P.W. 67-74

Abstract: Psocids are an emerging problem in stored grain and in grain processing facilities in the United States. We compared several methods for sampling psocids in wheat stored in steel bins – grain trier samples, cardboard refuges on the surface of the grain and near the bin hatch, and automated sampling using the StorMax Insector system. The psocid species found were *Liposcelis entomophila* in 2005 and *L. decolor* in 2006. The numbers of psocids in cardboard refuges on the wheat surface were low immediately after bins were filled in July 2005, peaked in October, dropped to almost zero in December as temperatures decreased during winter, and then remained at low levels until the study was ended in April 2006. In 2006, the number of psocids in surface refuges increased gradually from August to mid-October, and remained at this level until the study ended in early November. The number of psocids in cardboard refuges and in Insector probes was indicative of the number of psocids in grain samples in both years. The results indicated that cardboard refuges or Insectors may provide an efficient method for sampling psocids in bins of wheat, and that psocid populations can increase quickly to high levels during storage even though they are low early in the storage period.

Evaluating treatment efficacy in commercial food facilities: Insights gained from small-scale simulated warehouse experiments

Campbell, J. F. Toews, M. D., Arthur F. H. 75-83

Abstract: Although critical to a successful IPM program, it is challenging to evaluate treatment efficacy in commercial food facilities because of the inability to obtain absolute estimates of

insect population levels. These populations are spatially fragmented and occupy cryptic habitats, such as equipment, packages, and the structure of buildings that cannot be identified and sampled for practical and economical reasons. This leads to a number of important questions including (1) what impact are treatments such as surface, crack and crevice, or aerosol applications having on pest population dynamics, (2) how does application method impact suppression of established infestations and reduction of new infestations, and (3) how well do pheromone traps that indirectly sample from dispersing individuals represent the absolute population density and subsequent changes as a result of the treatment. While these questions cannot be accurately addressed in commercial facilities, they can be explored in small-scale simulated warehouses where resource amounts and distribution, and initial pest density can be controlled and refugia can be directly sampled to estimate absolute population levels. Using the red flour beetle, *Tribolium castaneum* (Herbst), as a model organism and replicated small sheds with shelving units containing hidden resource patches of flour as simulated warehouses, we have begun addressing the above questions. Results of one of these experiments are presented and the potential impact on how management programs should be implemented and evaluated in commercial food facilities is discussed.

The use of sex pheromone traps for cigarette beetle as a tool for IPM in a cigarette factory in Cape Verde islands

Carvalho M.O., Mexia A., Torres L. M. 85-92

Abstract: *Lasioderma serricornis* (F.) (Coleoptera: Anobiidae) is the most serious insect threat to stored tobacco and cigarettes on the Cape Verde islands. A monitoring programme using sex pheromone traps for the cigarette beetle was initiated to detect sources of infestation and to assess the risk of tobacco damage. Trials were conducted to obtain estimates of the mean density of *L. serricornis* and to analyse its spatial pattern. The manager of the cigarette factory used the trap records to assess risk and implemented an empirical action threshold of 10 insects/week/trap. The variability in the trap catches indicated an aggregated pattern and negative binomial distribution fitted the data more accurately. From the results obtained a sequential sampling plan was developed for classifying the pest status of *L. serricornis* based on complete counts from insects caught in the pheromone traps. Two sequential sampling techniques were used: the sequential probability ratio test (SPRT), as the adult population followed the binomial negative distribution, and Iwao's confidence interval method. It was shown that, using SPRT or Iwao's methods, managers can make decisions using six and 13 traps, respectively, with a minimum risk of incorrect assessment. After five years of using this strategy, the relative population density of cigarette beetle has decreased below the level at which it is considered serious.

Monitoring of insect populations by using adhesive surfaces of different colours in a dried fig warehouse in Southern Greece

Karlis G., Athanassiou C.G., Buchelos C.Th. 93-106

Abstract. Adhesive surfaces were suspended above the floor of a fig warehouse in the region of Kalamata, Southern Greece, which is the most important region for dried fig production in Greece. The surfaces of these traps were of five different colours: black, green, blue, white and yellow. Half the number was baited with TDA, the male attractant of several stored-product Pyralidae, while the rest remained unbaited. Monitoring was performed at weekly intervals from May 2002 until September 2002, by examining the adhesive surfaces for captured individuals and replacing them with new traps. Twenty-three insect taxa were found during the entire monitoring period. The most abundant species was *Plodia interpunctella* (Lepidoptera: Pyralidae) followed by the parasitoids *Habrobracon hebetor* (Hymenoptera: Braconidae) and *Cephalonomia* sp. (Hymenoptera: Bethyridae). These three species represented >85 % of the total number of individuals counted. Captures of *P. interpunctella* were continuously high, especially during summer months, and exceeded 30 adults/trap in early July. On the other hand, the numbers of parasitoids notably increased only during September. For *P. interpunctella* and *H. hebetor*, the colour of the sticky surface had no effect on the number of captured individuals. In contrast, more *Cephalonomia* sp. adults were captured on yellow than on black traps. More *P. interpunctella* adults were captured on traps far from the windows, in comparison with traps that were close to the windows, but this trend was evident only in the case of pheromone-baited traps. For both parasitoids, more adults were found on traps that were placed close to the windows. The separation of the sticky area into sub-areas, indicated that most *P. interpunctella* males were

found in the area above the pheromonic lure, while no specific trend was noted on the unbaited traps. For *H. hebetor*, most captures were recorded at the lowest part of the trap, while both parasitoids avoided the upper trap part. A noticeable proportion of the captured *H. hebetor* individuals were recorded at the marginal outlines (edges) of the sticky surfaces.

Monitoring mill moth (*Ephestia kuehniella* Zell.) by pheromone traps in Belarus

Kozich I...... 107-111

Abstract. The prevalence, biology and phenology of the Mediterranean flour moth or mill moth *Ephestia kuehniella* Zeller in flour mills and bakeries of Belarus were given. The dynamics of development in the closed heated rooms and influence of ecological factors on these changes are described, the use of pheromone traps for monitoring mill moths were given. Results of the researches for 2004 – 2006 on efficiency of the new synthesized samples of working substances for catching the pest under production conditions at different densities of insect populations were discussed. The most effective concentrations that allow carrying out monitoring and identifying mill moth occurrence, dependence between catching in the pheromone traps and their density on volume unit of a room is revealed. The catching of mill moths using synthetic sex pheromones, kayromones and new attractants in milling rooms, unpacked storage of flour storage rooms and bakeries is given. The results will allow to establish beforehand density of the Lepidoptera populations for the further drawing up of their activity forecast, damage and the application of various protection methods according to the pest number. The successful use of pheromones for mass trapping in grain processing enterprises of Belarus was demonstrated.

Potential of near infrared spectroscopy (NIRS) technology to discriminate between infestations of stored product pests in rice

Pascual-Villalobos M.J., Font R., De Haro-Bailon A., Riudavets J...... 113-117

Abstract. Contamination of cereal grains with insect pests is a commercial issue relevant to decision-making on the possible use of a commodity for food, feed or other industrial uses. Both the level of infestation and also the species of stored product pest and in which developmental stage it is found could be of practical importance. Sets of rice grain samples infested by eggs, larvae (0-100 individuals per 100 g) or adults prior to emergence (0-10 individuals per 100 g) of *Sitophilus oryzae*, *Rhyzopertha dominica* or *Sitotroga cerealella* were prepared with the aim of studying the potential of the NIRS technique to detect the level of infestation and /or to discriminate between insect species or stages of development. Preliminary data showed that it was possible to group egg, larval or adult infested rice samples within the *R. dominica* lot. Also, by PCA of spectral data a discrimination of *S. oryzae* from *R. dominica* adults inside kernels was obtained whilst this was not the case for larvae of *R. dominica* versus *S. cerealella*. To predict the level of *R. dominica* egg infestation in the grain, it was necessary to fit an equation with the second derivative of the log 1/R data to get 85% of variability. These results should be confirmed in further studies.

Monitoring of insect populations in a pasta factory and related facilities in Greece

Kaltsikes P. J., Athanassiou C. G., Goufa M., Repanis M., Bakodimos D., Gouveri M...... 119-125

Abstract. Trapping and sampling was conducted, in order to indicate insect populations in a pasta factory in Greece. Also, samplings in packaged pasta products were carried out, to indicate the potential presence of insects in the final product. For this purpose, Dome traps were placed in several areas of the factory and inspected for captured insect individuals, from May until December 2005. The most abundant insect species was found to be *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae), followed by *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Cryptolestes* spp. (Coleoptera: Cucujidae). For *T. confusum*, most adults were found at the areas where pasta is processed, while *S. oryzae* was mainly found at the mill area, especially at the points that raw grains enter the mill and at the wheat silos. Nevertheless, for all species, extremely few individuals were found at the storage areas of the final products, or in the areas where the product is packed, indicating that insect activity is low in these areas, and that infestation after processing and during initial storage is less likely in the factory's storerooms. Approx. 4500 packaged pasta products were taken between 2005 and 2006, placed in incubators at 27°C and 70% r.h., and examined for insect presence. No insects were found in these samples, which considered as an additional indication that the product is pest-free and any infestation occurs through invasion of insects that exist in the storerooms where the product is transferred

(super markets, large storerooms etc.). For this purpose, traps were placed at specific super markets and large storerooms, which contained the specific products, during the same interval, as above. Trap captures were considerably higher in these areas in comparison with the respective figures in the factory area, especially in the case of *S. oryzae*, which was by far the most abundant species. Also, many of the species found in these areas, such as *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) and *Lasioderma serricornis* (F.) (Coleoptera: Anobiidae) were not found in the traps in the factory areas. These data indicate that, in the majority of cases, infestation is more likely to occur at the end-point areas of the products through entrance of insects in the packaged products, rather than through insects that exist in the product before packaging.

New funnel pheromone trap for monitoring of moths in dusty places

Komorowska-Kulik J., Ignatowicz S., Sieminska E. 127-130

Abstract: A new funnel trap “Panko” that can deflect the dust and allow the use of a glue strip as the entrapment mechanism was compared with the funnel pheromone trap of “AgriSense”. The numbers of stored product moths trapped by the funnel pheromone trap “Panko” were similar or higher than those for the funnel pheromone trap “AgriSense”. Efficacy of the “Panko” trap in dusty areas seems to be higher than that of the “AgriSense” trap. The funnel pheromone trap “Panko” should be recommended for moth monitoring in dusty premises.

Biological control

Population dynamics of the natural enemies of stored product pests in cereal and dried fruit companies

Belda C., Pons M^a. J., Gabarra R., Riudavets J. 133-139

Abstract: The population dynamics of stored product pests and their naturally occurring parasitoids were assessed for several months in different companies which stored rice and dried fruits. Pests and parasitoids found in the different companies were identified and their levels assessed. Three different traps types were used to capture the species of interest: pheromone traps, yellow sticky traps and light traps. Monthly samples of the different products were also taken randomly. Presence of natural enemies was observed in every company and each company had different species and amounts of natural enemies and pests. The results showed that the traps used had different capture levels. Light traps had higher captures per trap than yellow traps in relation to natural enemies. Pheromone trap turned out to be very efficient for capturing Lepidopteran pests. Finding a naturally existing population of natural enemies which could be able to control the pest efficiently is essential, for application as an alternative to pesticides. The present results, though preliminary, show the possibility of instauration of biocontrol based on the naturally occurring populations of natural enemies, as they seem to adapt to the host cycle.

The biology of *Lariophagus distinguendus* a natural antagonist of stored grain beetles – film presentation

Collatz J., Wyss U., Steidle J.L.M. 141

Abstract only

Biological control of *Anobium punctatum* in infested books, using the parasitoid

Lariophagus distinguendus - preliminary results

Wilamowski, A., Kessler, I. Rabin, I., Prozell, S. Navarro, S. 143-147

Abstract: A severe infestation of thousands of books by *Anobium punctatum* was discovered in an Israeli library. Initial successful treatment was carried out, involving fogging the library space and freezing the books at -30°C. Other known methods for treating books (anoxia or methyl bromide), involve removal from the library and treatment is very problematic. BIP Company from Berlin suggested checking the possibility of biological control of the infested books using the parasitoid wasp, *Lariophagus distinguendus* while the books remained on the library shelves. Research has proven that the above mentioned wasp has the ability to identify and parasitize host larvae in closed and limited spaces such as grains of rice or pulses, and to reduce the populations of stored pests like *Sitophilus granarius* or Bruchidae. During each of three months, wasp pupae supplied by BIP were released in a closed library room in which infested books were concentrated in an open carton exposed to the wasps. Infested control books were placed in material-covered cartons. 46 % of the *Anobium* larvae among the exposed books were found dead. 86% of the

larvae were found live in the control, covered box. In parallel, *Sitophilus granarius* larvae in wheat kernels, in four gauze packages with a mesh width of 1.5 mm, were placed amongst cartons of uninfested books for 5 days and exposed to the wasps. There was no emergence of adult *S. granarius*. However, emergence of wasps, were found which had developed in the host larvae. These results indicate the ability of the wasps to identify the host and to parasitize them, either between or inside the books. These trials show the potential for *Lariophagus distinguendus* to serve as a biological control agent in books on shelves. More experiments are necessary to make this potential practical.

Virulence of isolates of the entomopathogenic fungus *Beauveria bassiana* (Bals.)

Vuillemin to adults of *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae)

Draganova S., Staneva E. 149-154

Abstract: Bioassays with conidia of twenty isolates of the entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuillemin have been tested on adults of *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae). Newly emerged insects were treated indirectly with conidial suspensions (1×10^6 conidia/ml) of the isolates. Lethal effect of the isolates was evaluated as percentages of cumulative daily mortality due to mycoses. Virulence of each fungal isolate was estimated by values of the median lethal time (LT_{50}), calculated by probit analysis. Fourteen of the tested isolates caused a mycosis with rapid lethal effect. The first dead insects were noted on the second day. Mortality of *A. obtectus* adults in variants treated with conidial suspensions of the isolates 412 and 414 of *B. bassiana* increased from 7.5% and 1.25% on the second day to over 75% on the fifth day and up to 100% on the sixth day. Isolates 225, 229 and 343 caused the lowest lethal effect – 49.17%, 39.17% and 53.75%, respectively, on the 10th day. The isolates 412, 414 and 417 had the highest virulence to *A. obtectus* adults. The average values of the median lethal time (LT_{50}) of the isolates were 3.426, 3.776 and 3.832 days, respectively. The values of LT_{50} calculated at significance level $p < 0.05$ varied within narrow confidence intervals from 3.119 to 3.773, from 3.549 to 4.018 and from 3.556 to 4.129 days. Significant difference between the virulence of the three isolates couldn't be found. The isolates 225 and 229 of *B. bassiana* had the lowest virulence. Their values of LT_{50} varied within the confidence intervals from 13.080 to 18.920 days, with an average value of 15.730 days and from 11.620 to 15.400 days with an average value of 13.790 days, respectively.

Experiences with beneficial insects for pest control in storage buildings and processing units

Meierhofer B., Fassbind D., Brand S., Kraaz I., Zingg D., Wyss G.S. 155-159

Abstract: In a three year project, a practical approach for the control of stored-product pest insects in storage buildings and processing units is developed using the laboratory-mass-reared parasitoids and predators *Trichogramma evanescens*, *Habrobracon hebetor*, *Lariophagus distinguendus* and *Anisopteromalus calandrae*. *T. evanescens* and *H. hebetor* are mainly applied against *Plodia interpunctella*, but also against *Ephestia kuehniella*, *E. elutella* and *E. cautella* in mills, silos and bakeries as well as in storage buildings with big bags. *L. distinguendus* and *A. calandrae* are mainly applied against *Stegobium paniceum* in processing units. The evaluation of the pest development within the storage units was carried out by a comprehensive insect trap survey and a comparison was drawn to previous years where conventional pest control was still used. After the first year of experience a positive conclusion can be drawn. Four out of eight trials did not need any additional chemical treatments and three further trials needed only local chemical treatments based on water formulated compounds. However, limitations regarding the successful introduction of beneficials such as insufficient cleaning or constructional deficits became obvious. Further trials during this and next year will be carried out to confirm the experiences of the first year.

***Lariophagus distinguendus* Förster (Hym.: Pteromalidae): development on *Sitophilus granarius* L. (Col.: Curculionidae) at low temperatures**

Stengård Hansen L. 161-164

Abstract: The granary weevil *Sitophilus granarius* is an important pest in grain stores throughout temperate regions. The larval parasitoid *Lariophagus distinguendus* is a potential candidate for biological control of this pest. In cooler climates the successful use of this parasitoid depends on its ability to survive low temperatures during winter. Investigations have been carried out at the

DPIL to determine development rates of *L. distinguendus* at temperatures down to 15°C. Furthermore, an investigation was set up to simulate conditions in a grain store during winter. Grain infested with *S. granarius* and *L. distinguendus* was gradually cooled to a target temperature of 5°C and maintained there for 15 weeks. The grain was then gradually transferred to room temperature and emergence of *S. granarius* and *L. distinguendus* was registered. Preliminary results of these investigations are presented.

Development of a mass rearing device for the use of *Lariophagus distinguendus* (Förster) against *Sitophilus granarius* L. in grain

Niedermayer S., Steidle J.L.M. 165-169

Abstract: One of the major pests of stored products in Europe is the granary weevil *Sitophilus granarius* L. To control this pest, *Lariophagus distinguendus* (Förster) can be used. It showed good results in various laboratory experiments and is commercially available in different European countries. Nevertheless the existing system of shipment and release has also some disadvantages that should be improved. Therefore, the aim of the present study is to develop a mass rearing device which can be placed in grain stores to obtain a continuous release of the wasps throughout the season. So far, the studies revealed the following results:

- Experiments under (extreme) climate conditions of grain stores showed that the parasitisation ability of *L. distinguendus* during cold months depends on the minimum temperature and on the maximum temperature in warmer months. Mean daily temperatures are less important. Thus, the use of *L. distinguendus* might not only be constrained by cold temperatures during winter, but also by high temperatures in summer.
- In release experiments in empty storages *L. distinguendus* females were able to locate hosts over a maximum distance of up to 5 m. Thus, distances between mass rearing devices should not be larger than 10 m.
- *L. distinguendus* is able to recognize and parasitise the alternative host *Acanthoscelides obtectus* in beans. Thus, *A. obtectus* can be used as host for the rearing of the wasps in mass rearing devices in grains instead of granary weevils, which would not be accepted by grain store owners.

Studies on storage, release and host finding of *Trichogramma evanescens* to control

Ephestia kuehniella

Tuncbilek A.S., Canpolat U., Sumer F. 171-179

Abstract: The Mediterranean flour moth (MFM), *Ephestia kuehniella* Zeller (Lep.: Pyralidae), is a serious pest of flour and feed mills. Parasitoids from the genus *Trichogramma* are of interest for control of pyralid moths in flourmills. The objective of the present study was to evaluate the efficacy of inundative releases, the host-finding ability and feeding method of *Trichogramma evanescens*. Controlled releases of *T. evanescens* were made in metal boxes. Wheat flour in small sacks was placed the metal boxes and then 10 female and 10 male adults of *E. kuehniella* and about 1500 parasitized eggs were simultaneously placed in metal boxes three times each until the host adults died. Despite a reduction of *E. kuehniella* population compared with non-release control population, the parasitoid was not able to suppress the population to economic threshold level in infested boxes. When *T. evanescens* adults were stored at 4°C for 7 days and at 10°C for 15 days, storage had no significant effect on parasitisation, and adult and female emergence compared with untreated control, but stored at 4°C for 11 days showed significant reduction in emergence. Host finding capacity of the wasp was also tested in u-shaped plates (100, 120 and 200 cm) using *E. kuehniella* eggs as host. The release distance did not influence the parasitism of the wasp (from release point to the host eggs) and it effectively parasitized as far as the distance of 200 cm. In another test we also compared conventional feeding method to glass micropipette; the females parasitized significantly higher numbers of hosts when honey was offered in a glass micropipette than the conventional.

Factors affecting the attachment of conidia of *Metarhizium anisopliae* (Metschnikoff) Sorokin (Deuteromycotina: Hyphomycetes) to different body parts of *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae) adults

Kavallieratos N.G., Wakefield M.E., Athanassiou C.G. 181-190

Abstract: Laboratory experiments were carried out to assess the effect of temperature and relative humidity (r.h.) on the attachment of conidia of the entomopathogenic fungus *Metarhizium anisopliae* (Metschnikoff) Sorokin (Deuteromycotina: Hyphomycetes) to the elytra, femur, tibia,

tarsus, sternite VI and sternite VII of adult *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae). In addition, the attachment was measured on different grain commodities treated with *M. anisopliae* dry conidia. The commodities tested were barley, maize, rice and wheat. In a first treatment, adults of *T. confusum* were exposed on wheat treated with *M. anisopliae* conidia at three temperatures (20, 25 and 30°C) and two r.h. levels, 55 and 75 %. Dead adults were removed from the treated substrate after 7 days of exposure and stored at 0°C. In a second trial the treated grain was maintained at 25°C and 75 % r.h. for 7 days, stored at 0°C. In both cases the attachment of conidia was evaluated by counting the number of conidia, using a scanning electron microscope (SEM). The tarsus and tibia had the lowest numbers of attached conidia compared to the other parts of the body, for all combinations tested. The highest numbers of attached conidia were found on sternites VI and VII, especially on sternite VI, where significantly more conidia were found at 20 and 25°C and 55 % r.h. Significantly higher numbers of attached conidia were found on the femur at 30°C than at 20°C at both r.h. levels. Wheat had significantly higher numbers of attached conidia compared to those on barley or rice. The present results indicate that conidial attachment of *M. anisopliae* to the cuticle of *T. confusum* adults is affected by temperature, r.h. and commodity.

Efficacy of submultiples doses of *Bacillus thuringiensis* compounds against the Mediterranean flour moth *Ephestia kuehniella* (Zeller) (Lepidoptera: Pyralidae)
Kontodimas D., Nikoloudies K.J. 191
 Abstract only

***Enterococcus mundtii*, a pathogenic bacterium to *Ephestia kuehniella* Zeller**
Yaman M., Aslan I. 192
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Effect of gamma radiation and cold storage on emergence and life time adults *Venturia canescens* Gravenhorst (Hymenoptera: Ichneumonidae) parasiting larvae of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae)
Celmer-Warda K., Ignatowicz S. 193-201

Abstract: Laboratory studies were conducted on the effect of gamma radiation and cold storage on emergence and life time of adults of *Venturia canescens* Gravenhorst (Hymenoptera: Ichneumonidae) parasiting larvae of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae). Adults of *V. canescens* emerged from *E. kuehniella* and irradiated with a dose of 0.2 or 0.4 kGy were as fertile as the adults that emerged from untreated hosts (control). Body mass of parasitoid adults emerged from moth larvae irradiated with a dose of 0.2 or 0.4 kGy of gamma radiation was similar to that of the adult wasps emerged from non-irradiated larvae. Storage period of irradiated and parasitized moth larvae at low temperatures (5°C) did not inhibit the development of parasitoids, but increased their mortality rates, when they were exposed to ambient temperature (25°C). Fertility of emerged adults of *V. canescens* was not affected by the period of storage at a low temperature. Longevity of parasitoid adults that emerged from 0.2 or 0.4 kGy irradiated host larvae was similar to those parasitoids that emerged from untreated hosts. These finding indicate that *E. kuehniella* larvae irradiated with low gamma radiation doses may be used for the mass-culture of *V. canescens* parasitoids.

Phytochemicals

Repellent activity and persistence of the essential oils from *Carum copticum* and *Vitex pseudo-negundo* on *Tribolium castaneum*
Sahaf B.Z., Moharrampour S., Meshkatsadat M.H., Filekesh E. 205-210

Abstract: The protection of stored agricultural products against insects is carried out mostly with chemical insecticides. These insecticides have harmful effects on the environment. The current study showed that plant extracts and essential oils may have potential as safe alternative compounds to currently used insecticides. Essential oils are volatile and can act like fumigants offering the prospect for use in stored-product protection. Some also have the ability to repel insects. The objective of the present study was to test the possible properties of essential oil vapours of the medicinal plants, *Carum copticum* and *Vitex pseudo-negundo* against *Tribolium castaneum* (Herbst), and to elucidate their repellency effect and half-life time. The experiments were conducted at 27 ± 1°C, 60 ± 5 % R.H. and in darkness. The essential oils were obtained

from seeds of *C. copticum* and dry leaves of *V. pseudo-negundo*, subjected to hydrodistillation using a modified Clevenger-type apparatus. Results showed that *V. pseudo-negundo* causes a greater degree of repellency to *T. castaneum*. The highest concentration (3 µl/ml acetone) of the *C. copticum* and *V. pseudo-negundo* oils cause 87.50 and 100% repellency on adult insects, respectively. The persistence or half-life time of the *C. copticum* (36.24 days) oil was higher than that of *V. pseudo-negundo* (2.98 days). The results demonstrated the efficacy of these two essential oils for use in organic food protection. They can prevent the infestation of the stored-product pests to the warehouses.

Insecticidal activity of volatile monoterpenoids to *Sitophilus oryzae* L. (Coleoptera: Curculionidae), *Rhyzopertha dominica* Fabricius (Coleoptera: Bostrichidae) and *Cryptolestes pusillus* Schönherr (Coleoptera: Cucujidae)
Lopez M.D., Pascual-Villalobos M.J. 211-219

Abstract: Botanicals have potential to be developed as low risk insecticides, following the consumer demands of safe and quality food. Plant essential oils are a source of volatile monoterpenoids which are being studied in our research group as alternative products to control stored rice pests. Laboratory bioassays were performed in 15 ml volume glass vials at 30°C to assess mortality after 24 h against *Sitophilus oryzae*, *Rhyzopertha dominica* and *Cryptolestes pusillus*. Doses causing 50 % mortality in insects ranged from 1.9 to 196 µg / ml of air volume and the decreasing order of sensitivity for test species was *C. pusillus*, *R. dominica* and *S. oryzae*. The most active products were estragole, camphor, linalool, carvone, eugenol and *E*-anethole with LC₅₀ within the range 1.9-7.3 µg / ml and with some selectivity depending on the pests. Repellent effects of monoterpenoids were observed for linalool to *C. pusillus*.

Toxicity and repellency of essential oils of *Lippia adoensis* from two agro-ecological zones in Cameroon to *Prostephanus truncatus* and two strains of *Sitophilus zeamais*

Nukenine E.N., Adler C., Reichmuth C. 221-230

Abstract: Essential oils extracted from the leaves of *Lippia adoensis*, harvested from two agro-ecological zones (Mbe and Dang) in Cameroon were evaluated in the laboratory for toxicity and repellency to *Prostephanus truncatus* and Cameroonian and German strains of *Sitophilus zeamais*. The essential oils were analyzed by gas chromatography. Maize grains were coated with the oils at four rates (10, 20, 40, 80 µl/40 g) for the assessment of weevil mortality over an 8-day period. Repellency tests on filter papers included five dosages (0.5, 1, 3, 5 and 10 µl/half disc) of the essential oils. The three dominant constituents were thymol (50,9%), p-cymene (8,9%) and carvacrol (8,3%) for *L. adoensis* from Mbe (LAM), and geraniol (37,2%), linalool (27,7%) and cis, beta-farnesen (10,8%) for *L. adoensis* from Dang (LAD). The two types of *L. adoensis* were generally significantly toxic to *P. truncatus* and both strains of *S. zeamais*, although the action of LAD was slower than that of LAM. The 6-day LD50-values indicated LAD was more toxic to the German (12.3 (10.5-14.0) µl/40 g) as compared with the Cameroonian strain (29.7 (17.3-54.2) µl/40 g) of *S. zeamais*, but both strains responded similarly to LAM (7.1 (4.8-9.0) and 6.6 (4.3-8.3) µl/40 g, respectively). Both essential oils were highly repellent to the weevils but much less so to *P. truncatus*. Although the essential oil from *L. adoensis* may provide effective control of *S. zeamais* and *P. truncatus* on maize, there is the need for testing the toxicity of the plant species from different agro-ecological zones to the beetles in different environments, if the plant is to be of value in the integrated management of *S. zeamais* in Africa.

Effectiveness of novel compounds for the control of stored product mites

Wakefield M.E., Ford H.L. 231-241

Abstract: Stored product mites are prevalent on post harvest cereals in the UK and their presence may result in direct damage to the grain, cause occupational allergies in workers and reduce palatability of cattle-feed and growth rate of pigs and poultry. Best practice for grain storage relies on the use of physical control methods such as drying and cooling but mites may still be present in the surface layers of grain due to absorption of moisture at the grain surface. Stored product mites have shown resistance to organophosphate insecticides and there is a need to develop alternative control methods. As part of a wider study to examine possible target sites for storage mite control agents, we examined four compounds with potential to interfere with the mite cuticle, either by disruption of chitin synthesis or the sclerotisation process. The compounds examined were flufenoxuron, lufenuron, kojic acid and nikkomycin Z. The compounds were

incorporated in the mite diet and the effect on mortality of the flour mite, *Acarus siro*, and subsequent population growth was determined. Kojic acid and nikkomycin Z had no effect on mite population growth at the F₂ generation. Lufenuron at 100mg/kg resulted in a significant decrease in numbers at the F₂ generation (79% population inhibition). Flufenoxuron also resulted in significant decreases in population growth (> 99% population inhibition) at both 10mg/kg and 100mg/kg. Subsequent tests with lufenuron also showed a significant reduction in population growth at the F₂ generation when tested against *Tyrophagus longior* at concentrations of 10mg/kg and 100 mg/kg and a reduction in population growth at the F₂ generation at 100 mg/kg for *Lepidoglyphus destructor*. The effectiveness of chitin synthesis inhibitors appears to depend on the particular mode of action. The study has shown that disruption of cuticular processes would provide an effective mode of action for novel control agents. The potential of such compounds to act as effective control agents is discussed with regard to time for effect, application methods, cost and residues.

Comparative fumigant toxicity of *Rosmarinus officinalis* and *Artemisia sieberi* against *Tribolium castaneum*

Ahmadi M., Moharramipour S., Zolfagharieh H.R. 243-247

Abstract: Essential oils of *Rosmarinus officinalis* L. (Lamiaceae) and *Artemisia sieberi* Besser (Asteraceae) collected from Tehran province were examined for their potent fumigant toxicity against a major stored-product beetle, *Tribolium castaneum* (Herbst). Dry ground leaves from each plant were subjected to hydrodistillation using a modified cleverger-type apparatus. The mortality of 1-3 day old adults of the insect increased with concentrations from 2.50 to 8.93 µl/l air for *R. officinalis* and 3.57 to 28.57 µl/l air for *A. sieberi*. The LC₅₀ and LC₉₅ values to the selected essential oils were 6.84 and 9.66 µl/l air for *R. officinalis*, and 19.40 and 60.89 µl/l air for *A. sieberi* respectively. The test results based on a 95% confidence interval indicated that *T. castaneum* was more sensitive to *R. officinalis* than *A. sieberi*. Fumigant effects of these essential oils were considered to warrant further research on their potential for commercial use against stored-product insects.

Fumigant toxicity of essential oil from *Tanacetum polycephalum* against *Tribolium castaneum* and *Callosobruchus maculatus*

Arabi F., Moharramipour S. Sefidkon F. 249-252

Abstract: In an attempt to find a natural and cheaper method for the control of stored product pests, fumigant toxicity of essential oil from *Tanacetum polycephalum* L. (Asteraceae), was tested against adults of two stored product insects, *Tribolium castaneum* (Herbst) and *Callosobruchus maculatus* (F.). Dry aerial parts of the plant were subjected to hydrodistillation using a modified cleverger-type apparatus. In this study, fumigant toxicity was tested against 1-7 day old adults of *T. castaneum* and *C. maculatus* with five replications at 25±1°C and 65±5% RH under a dark condition. LT₅₀ values calculated as the time to attain 50% mortality of tested insects during fumigation were determined at four different concentrations. For *T. castaneum*, LT₅₀ values ranged from 7.43 h for the lowest dose (32 µl/l air) to 5.2 h for the highest dose (483 µl/l air). The estimate of LT_{50s} for *C. maculatus* was decreased from 8.0 h for 32 µl/l air to 6.2 h for 483 µl/l air. Probit analysis showed that *C. maculatus* (LC₅₀ = 0.90 µl/l air) was more susceptible than *T. castaneum* (LC₅₀ = 10.68 µl/l air). It was found that plant essential oils particularly *T. Polycephalum* could be used either as a safe pesticide or a model for a new synthetic pesticide to control stored-product pests.

The effect of *Mentha piperita* L. and *Geranium robertianum* L. on the course of population processes of the lesser grain borer *Rhyzopertha dominica* F. (Coleoptera, Bostrichidae)

Klyts M. 253-259

Abstract: The subject of the investigations was the lesser grain borer *Rhyzopertha dominica* F. The aim of the studies was to determine the effect of the peppermint (*Mentha piperita* L.) and Herb Robert (*Geranium robertianum* L.) on the population processes of *R. dominica*. The herbs were powdered and added to wheat – an optimal nutrient for this insect species – in the proportion of 0.5 g herbs to 40 g wheat. The experiments were conducted under laboratory conditions in an incubator, at a temperature of 28°C and at 60 ± 5 % relative humidity (r. h.). The results obtained allow us to state that the addition of Herb Robert to the wheat had a greater limiting effect on the lesser grain borer population than the addition of peppermint. Herb Robert

kept the population at a very low level during the whole time of the investigations. It also, caused an increase in population mortality in comparison with the mortality of insects feeding on wheat only. Moreover, the addition of both Herb Robert and peppermint to the wheat substrate caused an increase in female mortality. Consequently, we deduced that the females are more sensitive to the effect of the chemical compounds in these plants. The compounds in the powdered Herb Robert demonstrated the properties of an antifeedant for this insect species.

Effectiveness of bitterbarkomycin against *Prostephanus truncatus* (Horn) (Coleoptera: Bostrychidae), *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) in stored maize

Milonas D., Athanassiou C.G., Maistrou S., Saitanis C.J. 261-266

Abstract: The insecticidal effect of bitterbarkomycin (BBM), which is a sesquiterpene extract from the plant *Celastrus angulata* Maxim. (Celastrales: Celastraceae), was evaluated at the dose rates of 0.01, 0.05 and 0.1 ppm on stored maize, against adults of three stored-grain beetle species, the lesser grain borer, *Prostephanus truncatus* (Horn) (Bostrychidae), *Rhyzopertha dominica* (F.) (Bostrychidae), the larger grain borer, and the rice weevil, *Sitophilus oryzae* (L.) (Curculionidae). Mortality was measured on treated maize after 7, 14 and 21 d of exposure. From the species tested, *S. oryzae* was by far the least susceptible, since mortality did not exceed 13 % even after 21 d of exposure on maize treated with the highest BBM dose. At the same conditions, *R. dominica* mortality reached 100 % after 14 d of exposure while at 0.01 ppm of BBM, approx. 55 % of the exposed *R. dominica* adults were dead. In the case of *P. truncatus*, mortality, after 21 d, was 100 % even at the lowest dose rate. The present results indicate that BBM can be used with success to protect stored maize against *R. dominica* and *P. truncatus*, but higher dose rates and longer exposures are needed for *S. oryzae*.

Insecticidal activity of essential oil from *Vitex agnus-castus* against *Callosobruchus maculatus*

Moharrampour S., Arabi F., Bagheri H. 267-270

Abstract: To control stored product insect pests, studies are increasingly focused on plants with insecticidal activity. In this study, fumigant toxicity of essential oil from *Vitex agnus-castus* L. was assessed against *Callosobruchus maculatus* (F.). Dry aerial parts of the plant were subjected to hydrodistillation using a modified Clevenger-type apparatus. Fumigant toxicity was tested against 1-7 days old adults of *C. maculatus* with five replications at 25±1°C and 65±5% RH in dark condition. Mortality at 37 µl/l air reached 40% after 24 h exposure. While at 370 and 556 µl/l air mortality was about 50% after 12 h exposure. At the same concentrations, the mortality increased to more than 90% after 21h. At the highest concentration (740 µl/l air) 100% of mortality was observed after 18 h exposure. The LC₅₀ value of the oil was estimated to be 219.46 µl/l air (95% fiducial limits: 147.32-346-73 µl/l air). These results indicated a strong activity of the oil on *C. maculatus*. So it is suggested that natural pesticides based on plant essential oils may represent alternative stored-product protectants whose time has come.

Physical, chemical and other techniques for stored product protection

Susceptibility of life stages of *Tribolium confusum* du Val. to gaseous ozone

Isikber A.A., Öztekin S. 273-279

Abstract: In this study susceptibility of life stages *Tribolium confusum* du Val. to gaseous ozone was tested. The toxicity of gaseous ozone at high initial concentration of 19.4 mg/L for a 2-h exposure period against all life stages of *T. confusum* was studied. Susceptibility of all life stages of *T. confusum* to ozone fumigation for a 5h of exposure period in the presence of two kg of wheat was also tested. Toxicity data for empty space ozone treatments indicated a remarkable difference in susceptibility between life stages of *T. confusum*. Ozone treatment resulted in very low mortalities of the adults, pupae and eggs of *T. confusum*, ranging from 4.2 to 14.1 % while the only larvae stage had a high mortality (74%). Adults, eggs and pupae of *T. confusum* were the most tolerant to ozone treatment, while the larvae were easy to kill. For every half-hour flushed ozone fumigation for 5-h in the presence of commodity, there was a significant difference in the mortalities of adults, larvae, pupae and eggs of *T. confusum* placed on top and the bottom of two kg of wheat. These results indicated that gaseous ozone could present a problem of penetration into a commodity. Toxicity data for half-hour flushed ozone fumigation in the presence of

commodity also indicated a remarkable difference in susceptibility between the life stages of *T. confusum*. The larvae placed on the bottom of two kg of wheat were easily killed, whereas eggs, pupae and adults of *T. confusum* were still tolerant. These findings indicate that ozone treatment resulted in a remarkable difference in susceptibility of the various life stages of *T. confusum*.

Application of ozone as fumigant to prevent unwanted biological activity in stored grain

Hansen P. 281

Abstract only

Combination of biological control and CO₂ treatments against *Plodia interpunctella* (Hübner)

Pons, M^e. J., Castañé C., Riudavets J. 283-287

Abstract: The Indian meal moth (*Plodia interpunctella* (Hübner)), is one of the most important pests of stored products and structures in Spain. *Blattisocius tarsalis* (Berlese) (Acari: Ascidae) is a native predatory mite of Lepidoptera eggs. Biological control with *B. tarsalis*, as well as CO₂-comprising modified atmospheres at atmospheric or high pressure, was evaluated in the laboratory. *B. tarsalis* was able to prey on *P. interpunctella* and to reduce its population. Dosages with modified atmospheres, needed for the control of *P. interpunctella*, were also effective for the control of the natural enemy.

Effectiveness of DEBBM-P, a new enhanced diatomaceous earth formulation for the control of *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae) on stored wheat

Wakil W., Ashfaq M. 289-294

Abstract: To control one of the main insect pests of stored wheat, *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae), a new enhanced formulation of a diatomaceous earth (DEBBM-P) was assessed in the laboratory for its efficacy against this insect pest. The new enhanced formulation DEBBM-P combining diatomaceous earth (DE) and the plant extract bitterbarkomycin (BBM), developed by Diatom Research and Consulting Inc., Canada, was applied at 75, 100 and 125 ppm on wheat and the bioassay was conducted in the laboratory at 30°C and 65 % r.h. The adults of the insects were exposed to treated wheat for 14 d and 21 d and the mortality was assessed by counting dead and live adults. After the assessment of the mortality, the replications were again retained for the next 63 d for the emergence of progeny. After 21 d of exposure, the mortality of *Tribolium castaneum* was 100% at all dose rates; also there was no emergence of the progeny. It was concluded that the enhanced DE formulation DEBBM-P is more effective than other DE formulations available in the market against stored grain insect pests.

Distribution and efficacy of aerosol insecticides in commercial facilities

Arthur F.H., Campbell J.F. 295-301

Abstract: Aerosol insecticides are being viewed as a potential alternative to fumigations in commercial milling, processing, and storage facilities. Although there are a number of insecticides and delivery systems available for use, there are little published data regarding efficacy and performance in actual commercial sites. Factors such as the specific insecticide and distribution system, susceptibility of the target pest, availability of a food source, the configuration of equipment, machinery, and processed food products inside a facility, and seasonal history of pest populations can all affect insect control when using aerosols. Data from current field studies will be used to illustrate and describe the impact of these factors and how they can affect efficacy of aerosol insecticides.

Evaluation of the knockdown activity of some pyrethroids on different types of surfaces against larvae of *Plodia interpunctella* larvae (Hbn.) (Lepidoptera: Pyralidae)

Locatelli D.P., Girgenti P., Caldiroli A., Stampini M. 303-311

Abstract: The knockdown activity after 10, 15, 20, 30, 45 min and 1, 2, 24, 48 h and the mortality after 24 and 48 h against mixed populations of the 2nd instar and the 4th instar larvae (♀♀; ♂♂) of *P. interpunctella*, were evaluated. Larvae were placed in contact for 30 min on glass (g), vitrified tiles (vt), and porous tiles (pt), treated with two concentrated emulsifiable formulations (100 g solution/m²) based respectively on deltamethrin (15 mg a.i./m²) and microcapsulated permethrin (25:75) (300 mg a.i./m²) and an aerosol formulation (100 g/m²) of

synergized tetramethrin (180 mg a.i./m²) with piperonyl butoxide (950 mg a.i./m²). Tests were carried out 24 h after the treatment.

It was found that the 2nd instar larvae were more susceptible to the above active ingredients than the 4th instar ones; the lowest mean percentages of knockdown activity and mortality were recorded on *pt*. The mean percentages of knockdown activity of the 2nd instar larvae on *g* and *vt* ranged from 93 to 100% for tetramethrin and from 56 to 100% for deltamethrin; they were always lower than 25% for permethrin. Means of knockdown activity, higher than 90% were recorded on *pt* from 1 to 48 h with deltamethrin while they were lower than 37% with the other active ingredients. The mean percentages of knockdown activity of the 4th instar larvae on *g* and *vt* with deltamethrin were respectively 89-93% for ♀♀ and 98-88% for ♂♂ after 48 h. With tetramethrin a lower knockdown activity for both sexes was recorded on *vt* (♀♀: 33%; ♂♂: 50%) compared to *g* (♀♀: 90%; ♂♂: 93%). Permethrin caused a mean percentage of knockdown activity after 1 h of 9-10% for ♀♀ and of 6-38% for ♂♂, while after 48 h they were 49-46% for ♀♀ and 46-51% for ♂♂. The highest knockdown activity on *pt* was observed for deltamethrin after 2 h (♀♀: 85%; ♂♂: 49%). The mean mortality of the 2nd instar larvae, higher than 80% after 48 h, was recorded on *g* and *vt* for tetramethrin and deltamethrin. The mean mortality was lower than 5% for permethrin. A mean mortality of 65% was observed on *pt* treated with deltamethrin, while it was less than 20% with tetramethrin and permethrin. The mean mortality of the 4th instar larvae was less than 35% for all active ingredients and tested surfaces.

Preliminary investigations about tolerance to phosphine in *Tribolium* strains

(Coleoptera; Tenebrionidae) in Italy

Savoldelli S., Süss L...... 313-317

Abstract: The Detia® Degesch Resistance Test Kit has been used to investigate the behaviour of *Tribolium* spp. adults in a phosphine atmosphere. This kit is a rapid laboratory bioassay which determines the phosphine tolerance of adult insects. Tests have been made on 4 strains of *Tribolium confusum* and 4 strains of *T. castaneum*. Three strains of each species were collected in different food industries while the fourth was a laboratory strain, reared for several years free of any chemical treatment. The concentration of 3,000 ppm of phosphine used in the tests has a narcotic effect on non-resistant insects within a few minutes, while insects with low phosphine susceptibility are still active after this time period. The results show significant differences related to the phosphine tolerance, particularly with reference to *T. confusum* strains. This laboratory kit is useful to recognize the resistance before a treatment with phosphine.

Evaluation of a new enhanced diatomaceous earth formulation (DEBBM-P) against

Rhyzopertha dominica (F.) (Coleoptera: Bostrychidae) on stored wheat

Wakil W., Javed A. 319-323

Abstract: A new enhanced diatomaceous earth (DE) based formulation (DEBBM-P) developed by Diatom Research and Consulting Inc., Canada, was evaluated for its efficacy against *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae). The applied concentrations on wheat grains were 75, 100 and 125 ppm at 30°C and 65% r.h. The mortality of adults was assessed after 14 and 21d exposure time to treated and untreated wheat and the number of the progeny was assessed after 60 days. Mortality was higher in the treated substrate as compared to the untreated control. The dose rate of 125 ppm of DEBBM-P gave 100% mortality 14d after treatment and there were no production of the progeny, similarly, the dose rate of 75 ppm gave 100% mortality 21d after treatment and 0.4 adults (F₁ generation) emerged per replication in comparison with the untreated controls which had 22.4 emerged adults. The results clearly indicate that the blending of DE's with other naturally occurring compounds may produce more toxic effect and the synergized DE based formulations may be significantly much effective even applied at low dose rates.

Efficacy of a new grain fumigant: ethyl formate/allyl isothiocyanate for the control of two stored grain beetles, the rice weevil, *Sitophilus oryzae* L. and the granary weevil, *Sitophilus granarius* L.

Ciesla Y., Rouzes R., Fritsch J., Ducom P...... 325-334

Abstract: The search for new molecules is essential in Europe in response to progressive phasing out of several post-harvest insecticides like dichlorvos, malathion or methyl bromide. Ethyl formate (EF) is a fumigant that is currently used in Australia on dried fruits. The Australian Stored Grain Research Laboratory (SGRL) has recently patented a mixture of EF with allyl

isothiocyanate (AITC) 95% / 5% (w/w) to reduce flammability and increase efficacy. It is a volatile liquid at ambient temperature and several trials carried out in Australia have shown very good control against wheat insects. In our laboratory, we began trials on wheat with *Sitophilus oryzae* L. and *Sitophilus granarius* L. because they are the most difficult stored grain insect to control. The mixture was tested with an application rate of 60 g/m³ mixture. Gas concentrations were measured by GC, FID for EF and NPD for AITC. A preliminary test was carried out with small samples of infested grain (200 g) in gastight drums. We obtained successful results with a control of 100% of adults and the most resistant stages (pupae and aged larvae) in less than 24 hours at 20°C. Other experiments were carried out under the same conditions with samples of 12 kg of heavily infested grain in 30-litre drums. Applications were made by introducing the mixture with a syringe on the grain in movement. Under these harsh conditions, high infestation rate and high gastight conditions, a high sorption quickly decreased the concentrations. In addition, anoxia took place very quickly, blocking insect respiration and thus the gas was not allowed to produce its toxic effect on cytochrome c oxidase. The mixture EF + AITC is a promising means to control grain insects and could be registered in integrated protection. However the conditions of its use have to be carefully studied.

Ethyl formate efficacy in combination with low pressure or at atmospheric pressure in mixture with CO₂ against the dried fruit beetle, *Carpophilus hemipterus* (L.) on prunes

Rouzes R., Ciesla Y., Dupuis S., Ducom P. 335-344

Abstract: The current disinfection of prunes is carried out with phosphine fumigation, after methyl bromide having been phased out for its action as an ozone-depleting compound. But phosphine fumigation takes time, typically the exposure time above 15°C is between 3 to 10 days according to the temperature. Low molecular weight volatile compounds such as ethyl formate (EF) are produced naturally by many types of fruit and vegetables. They also have been shown to have insecticidal properties. Ethyl formate is currently registered in Australia for dried fruit, but high doses are required to control pests such as the dried fruit beetle, *Carpophilus hemipterus* (L.) (8-h (25°C) at 73g/m³). To increase the EF efficacy, two methods were investigated. At normal atmospheric pressure (NAP), EF is mixed with CO₂ as in VAPORMATE[®] cylinders, 83.3 wt% CO₂ and 16.7 wt% EF. In a vacuum, pure EF is used at different levels of pressure. One insect species was tested, the dried fruit beetle, *Carpophilus hemipterus* (L.).

At NAP (EF + CO₂), fumigation of eggs showed that 9-h (20°C) exposures at 70g/m³ were more effective than 12-h (20°C) exposures at 50g/m³. Tests with pupae and adult stages, in NAP (EF+CO₂) fumigation showed that 100% mortality was achieved at 6-h (20°C) at 70g/m³; eggs were controlled at 9-h (20°C) at 70g/m³. In vacuum fumigation, adult stages were controlled at 40g/m³ in 2-h (20°C) at 800 mb. For the others stages, the fumigation dosage was doubled, going from 40g/m³ to 80g/m³. Pupae were already controlled, but only 93% of eggs died at 80g/m³ in 2-h (20°C) at 900 mb. Trials are to be done to find out the exposure time and the dosage necessary to kill 100% of the eggs. With both treatments, eggs were the most resistant stage, much more tolerant than pupae, and adults, the most susceptible. In conclusion, the use of EF at NAP either with CO₂ or pure in a vacuum is of great interest to quickly control dried fruit pests.

Integrated pest prevention methods during storage, transportation and handling

Contemporary enhancement of post-harvest IPM programs by selected physical methods

Fleurat-Lessard F., Dupuis S.A. 347-362

Abstract: During the last decade, dry-food processing industries are facing a major challenge in pest control with the ban of methyl bromide and the changes in food hygiene regulations aimed at consumer health protection, with a drastic reduction of chemical protectants for pest control in post-harvest systems.

In these post-harvest situations, the IPM approach represents the more convenient alternative to chemical control leading to both a reduction of pest infestation losses while complying with 'good hygienic practices' for food safety as a part of global HACCP quality assurance system. As an alternative to deregulated chemicals, the implementation of IPM in the dry food processing chains has three major advantages: i/ reduces pesticide residues risk in processed food; ii/ insures

the traceability of insect population along the food chain, from raw product storage to ready-to-eat food, through insect population monitoring systems; and iii/ prevents and controls infestation in the post-harvest food processing chain by non-chemical treatments. This last objective mainly relates to the replacement of chemical treatments by physical control methods in IPM programs.

The integration of physical techniques in IPM programs has significantly enhanced the efficiency of IPM programs in the post-harvest chain situations. The most popular physical techniques actually used in IPM are:

- High temperature killing of insect species infesting food processing facilities;
- Packaging design and testing for insect-proof properties;
- Modified atmosphere packaging of high added-value foods;
- Combination of different physical methods for food or feed product 'soundness assurance' before packaging (heat, CA, MA, high pressure);
- High-temperature preventative disinfestation of heat-insensitive food and feed products packaged in a plastic enclosure (MW or RF dielectric heating);
- Temporary deep-freezing of leguminous seeds for immediate post-harvest disinfestation.

The more recent advances in the integration of physical techniques into post-harvest IPM programs resulted from the support of specific computer programs. Additionally, the efficiency of physical treatments may be predicted by specific computer programs and more use of physical means in IPM program should help the stored-product quality managers to achieve efficient and customized IPM programs.

[Insect-proof packaging to avoid stored product insects](#)

[Adler C. 363-369](#)

Abstract: Insects are usually attracted by volatiles emerging through permeable packaging material, improper seals or other leaks in a given package. A number of package types were tested for invasion by neonate larvae of the Indian meal moth *Plodia interpunctella* and the rice weevil *Sitophilus oryzae*. Moth eggs could be found close to minute openings in packages, and neonate larvae were able to enter into the product. This was proven by finding intense webbing and grown larvae inside the package after a few weeks at 25°C and 65% r.h. Adult rice weevils were found to invade through existing openings but not to penetrate packaging material. Bags were often found to be leaky around the seams. In some cases product caught in the seam prevented proper sealing. Welding seams parallel to the edge of a bag were found safer than those at a right angle to the edge. Other bags were leaky because they obviously had been punctured by spike wheels during transportation within the facility of the producer. Clips that may be convenient for consumers and attractive in their appearance were found inappropriate as seals against stored product insects if used as the sole means to close a bag. In cardboard boxes leaks were found around the corners when the flaps did not overlap, when folding caused tension in the flaps; when glue had been applied only in spots, and when cartons were perforated to make opening more convenient.

[Aeration, fumigation by Siroflo®/Eco2Fume® and storage in modern bunkers and hermetic platforms under PVC - A review of three ecologically friendly technologies used for grain storage and protection in Cyprus](#)

[Varnava A., Yiasoumis D. 371-379](#)

Abstract: During the last 25 years three important ecologically friendly technologies were introduced and are successfully used in the grain storage industry by the Cyprus Grain Commission: a) Aeration (co-operation with Israel, from 1980 on), b) Fumigation technologies Siroflo® and Eco2Fume® (co-operation with Australia, from 1996 on) and c) Storage in modern bunker structures (co-operation with Australia, from 2000 on) and in hermetic platforms under PVC (co-operation with Israel, from 1988 on).

Aeration is extensively used in Cyprus to prevent negative changes in grain quality during storage. The energy needed under Cyprus weather conditions to reach a reduction of grain temperature by 10°C is about 1.0 kW/tonne (0.15 €/tonne), which negligibly increases the grain price.

Fumigation of grain in all metal and concrete silos is carried out by using the flow-through fumigation technology Siroflo®/Eco2Fume® (gas mixture of 2% PH₃ in 98% CO₂ in cylinders) maintaining a constant phosphine concentration of 45 ppm for 14 days. Fresh air is blown into the structures after fumigation to remove any PH₃ residues. Fumigation by using Siroflo®/Eco2Fume®

has many advantages in comparison to traditional grain protection methods by using phosphine tablets or liquid insecticides: this method provides a constant and fully controlled PH_3 gas concentration in non airtight storage structures, full automation of fumigation, improved safety in working environment, grain free from pesticide residues, more effective and cheaper grain protection, no need in transferring grain into an emptied bin, no need in handling dangerous residues of phosphine tablets. A weak spot is the low PH_3 concentration at the top 5-15 cm of treated grain and the long duration of fumigation. The cost for fumigation of 2200 tonnes grain in a vertical bin of 10.5 m diameter by using Siroflo[®]/Eco₂Fume[®] is 0.15 €/tonne in comparison to 0.15-0.16 €/tonne which is the cost for grain treatment with liquid insecticides or with phosphine tablets, plus 0.1-0.3 €/tonne energy expenses for grain transportation into an emptied bin needed when the last two methods are used. Nowadays in Cyprus phosphine tablets or liquid insecticides are not used any more for treating grain. Although there is a great deal of demand for Eco₂Fume[®] in North America, Australia and China, it seems that for some reasons Cytec, the only manufacturer of Eco₂Fume[®], will not proceed with its re-registration in EU. This obligates the CGC to look for other grain protection alternatives with at least the same advantages.

In Cyprus, beside vertical silos, modern bunker structures under UV PVC are also used to face abnormal situations, when additional storage space is required (e.g. in order to take advantages of low prices in the international market since Cyprus imports more than 90% of its needs in grain, or when there is a large local production). The bunker solution for grain storage has disadvantages and advantages. Negative aspects: high need in manpower for bunker operation, restriction in filling and opening during rainy days, danger of moisture condensation at the bunker apex. Advantages: successful protection of grain against damages caused by rain, birds and rats, ability to protect huge quantities of grain in a low-cost way, ability to take advantages of low prices in the international grain market, successful fumigation without pesticide residues. Bunkers are low cost structures (≈ 7.5 €/tonne capacity).

The collaboration among countries, organizations, companies and scientists is a powerful tool for the development, introduction and implementation of advanced technologies in the grain industry.