Sexual Pheromones – Modern Ecotechnologies for Ecosystem and Environment Protection

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Abstract
The paper is a synthetic study of the author's results regarding the possibility and advantages of the practical use of sexual pheromones. Synthetic sexual pheromones have been proved by ecological studies to be an efficient method both for the monitoring and control of pest insects. The efficient practical use of pheromones depends on the knowledge we have about the biology, ecology and behaviour of the target species. We present the concrete results obtained during the study of some species of harmful Lepidoptera Noctuidae in agroecosystems (with special reference to *Mamestra brassicae* L.), the research activity taking place from 1980 to 2000. The role of chemical mediators in general is suggested as ecotechnologies protecting the ecosystems and the environment.

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1. The role of chemical mediators in the environment

The complex aspects of integrated pest management appear implicitly associated with the problem of the environment. Every intervention made by the human factor in agriculture in order to control and combat pests may cause serious changes in agroecosystems and also in the adjacent natural ecosystems. They can have extraordinary impact on the environment and even on society.[1]

[1] David Pimentel, Environmental Aspects of Pest Management *(Report of Research. Cornell University Agriculture Experimental Station)* (1983): 185–201.

The complex and diversified discussion of the domain has made it possible to obtain some results of doubtless scientific value which have great importance from the point of view of application.[1]

The thorough knowledge of biocenoses and ecosystems requires systematic biological, ecological, ethological, pedagogical and hydrobiological studies, all "simplified" by means of biostatistical analyses which will lead in the end to a complex database offering the "optimal information" necessary to model, prognosticate and characterize the biocenoses and ecosystems complexly.[2]

At the level of agroecosystems, ecological engineering as a branch of ecotechinque is more and more involved in the thorough study of the relationship between the anthropic factor and the environment. There are important differences between the structure and functioning of agricultural and natural ecosystems. Agroecosystems are characterized by a continuous intervention; the maintaining of the ecological equilibrium becomes a permanent issue.[3]

Chemical mediators may be considered a remarkable ecotechnology mainly at the level of agroecosystems. Their use in the control and combat of pest insects is not primarily the consequence of the anthropic factor, only secondarily, the excessive multiplication of some pest populations being, after all, also the result of man's influence on (natural or artificial) ecosystems due to the reckless use of pesticides, of technical maintenance activities, deforestations etc.

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[1] David Pimental, "Environmental Aspects…", 185–201; Everett R. Mitchell, "Pheromones: as the Glamour and Glitter Fade – the Real Work Begins", *Florida Entomologist* 69 (1986), 1: 132–139.

[2] Gheorghe Stan, "Reproductive Biology, Mating Behaviour and Sex Pheromones in Pest Lepidoptera Species. Studies on Pheromonal Behaviour under Laboratory and Field Conditions in *Mamestra brassicae* L. and *Xestia c-nigrum* L. (Lepidoptera: Noctuidae)", *Buletin de Informare. Societatea Lepidopterologică Română* (Informational Bulletin. The Romanian Leptopterological Society), Suppl. 1 (1991): 87–133; Gheorghe Stan, "Ecological Management and Elaboration of the Management Decision in Pest Insects", *Environment and Progress* (Cluj-Napoca) 4 (2005): 381–388; Gheorghe Stan, "Particularities of the Long Term Ecological Monitoring in Pest Insects", *Environment and Progress* (Cluj-Napoca) 4 (2005): 389–399; Gheorghe Stan, Ioan Coroiu, Alexandru Crişan, "Sex Pheromones Used in Ecological Studies and Pest Lepidoptera Control", *Analele Universităţii Oradea, Biologia* 3 (1996): 46–59.

[3] Ioan Puia et al., *Agroecology and Ecological Ethics* (Cluj-Napoca: Ed. Academic Press, 2001), 481.

On the other hand, the use of chemical mediators (environmental hormones, social hormones, ecomones, telergones) should not be regarded as an exhaustive ecotechnology and methodology, but it is essential that it respects most of the ecotechnical rules.

The use of chemical mediators in studying pest populations with the help of special traps in the conditions of a systematic monitoring enables us to follow attentively the evolution of the population levels, the methods of direct combating (by mass capture or disorientation) being applied only as a final solution. Indirect combating, by supervising the populations, is the adequate biological form in order to avoid the drastic suppression of the populations, since, be it pest or not, each species has a well defined place and role as a link in the trophic chains and networks of the ecosystems.[1] It is a methodology (biotechnical procedure) which respects the principle of epharmony, each species having characteristic relationships with its habitat established in a long co-evolutional process.[2]

Pheromonal traps are an extremely efficient modality to carry out some complex eco-ethological studies on important species from different ecosystems or biocenoses (e.g. pest species, useful species, rare and endangered species etc.). Since they are easy to handle and can be disposed in the habitats where the adults' homing is, they offer unusual information, but it is necessary to use some attractive and specific pheromone variants.

The obtained results show that the data obtained by research with pheromonal traps are more accurate, than the data offered by light traps.

Some studies suggest that the use of some attractants made into multifunctional baits (pheromones + allomones + kairomones + synomones + phagoattractants + non-specific attractants) contribute to the optimization of the information referring to the biology, ecology and behaviour of the target species.

Biocenotic integrity and stationary equilibrium is based not only on trophic relationships or the behavioural models influenced by space,

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[1] Vasiliev B. Tschernyshev, "Ecological Pest Management (EPM). General Approaches", *Journal of Applied Entomology* 119 (1995), 5: 379–381; Peter P. Cobb, "Biorational Suppression of Pests in Landscapes", *Journal of Agricultural Entomology* 14 (1997), 3: 333–337.

[2] Oscar Wilmanns, "The Life History of Vineyard Plants: Findings and Thoughts to Life Strategies and Epharmony", *Carolinea* 57 (1999): 9–18.

all kind of resources, environmental factors or biotic factors, but also on specific, biochemical relationships, the results of a complex communication in which specific organs and ways are involved.

2. Sexual pheromones as chemical mediators and applied ecology

Applied ecology must be understood in two senses: as direct intervention (by means of solutions and methods) in the practical aspects regarding the quality of biotic environments, and also as indirect intervention, by acquiring information on the models of development, evolution, relationship with the habitat and behaviour of the target species, important from a scientific or a social-economical point of view.

Applied ecology has and offers solutions in a wide range of human activities, for example: it offers optimal farming methods and the protection of biotic environments; it ensures the normal functioning of natural and anthropized habitats; it optimizes practical actions by means of ecotechnologies; it offers a wide range of actions and possibilities for arranging and protecting biotic environments, preserving biodiversity, and the protection of nature in general; it confers the conceptual bases for the elaboration of ecological restoration methods in ecosystems and biomes degraded by natural or anthropic factors; it presents modalities for preventing and averting the factors and processes which affect and modify habitats (air, water, ground etc.); it fixes the principles according to which some modern methods are used to preserve the health of the biota and of the biotypes, directly affecting stress and people's health; it gives information on the laws which ensure the equilibrium of the biosphere in order to optimize the interventions in the economy of nature; it elaborates practical procedures and methodologies for controlled intervention in the environment (knowledge of the target species' biology, ecology and behaviour; being familiar with and combating sicknesses, pests, invasive species and species causing discomfort etc.); it improves, on bio-ecological bases, some modern technologies for the supervision of the environment, for the control, monitoring, management and combating of pests etc.; it lays the theoretical and practical foundations of some modern concepts for combating or decreasing all the negative actions which affect the biotic environments (pollution, desertification, deforestation, erosion, waste etc.); it makes people (and especially decision-makers) aware of and educates them in ecological issues.

At individual and implicitly populational level, biochemical relationships affect communication, adaptation to the environment, and

the maintaining of family hierarchies or "integrity". Practically, the biological, ecological and social significance of chemical mediators is somewhat difficult to discover, but they affect every organizational and functioning level of the living. Implicitly, the living system is also a ***biochemical system***, which produces a series of special metabolic products and functions according to the principle of the "emitter and receiver". The "emitter" releases a chemical signal, and the "receiver" has a ***chemoreceptor***. These information carrying substances are called ***chemical mediators*** (chemical messengers; semiochemicals; ectohormones; social hormones; ecomones; telergones, environmental hormones).[1]

Chemical mediators (chemical messengers) represent the *3rd and 4th generation of "pesticides"*. From among the 3rd generation the *endohormones* (e.g. juvenile hormones and their analogues) and *exohormones* (chemical messengers with intra- and interspecific action: allomones, pheromones, kairomones, synomones, antimonies etc.) are well-known.

The range of chemical mediators is wide, it contains a great number of compounds or chemical substances (attractants, inhibitors, stimulators, deterrents, repellents, toxins) each having a significant role in the individuals' biology and behaviour, mainly related to growth, development, nutrition, locomotion or reproduction. There is a ***trophobehavioural network*** in nature which greatly affects the study of pest monitoring and management by biological and biotechnical means.

It must be remembered that, indifferent of their category, these mediators ensure the stability of the specie populations in a biocenoses, and, at the same time, they also influence the regulation of the population level. The intervention of chemical mediators in intra- or interspecific behavioural relationships is shaped according to their type and according to the ***coevolution model*** (the insect–host plant, pray–predator, host–parasite relationship).

3. Sexual pheromones and general behaviour

Sexual pheromones have an evolutional importance, modelling the reproductive behaviour. A wide range of stimuli model this

[1] Gheorghe Stan, "Possibilities of Semiochemicals Use in Applied Ecology and Ecological Management of Pest Insects", in *Applied Ecology*, ed. Ioan V. Petrescu-Mag (Cluj-Napoca: Ed. Academic Press, 2007), 390; Gheorghe Stan, "Semiochemicals – Behavioural Mediators and Ecotechnologies for Environment Protection", *ECOTERRA* 15 (2007): 10–12.

behaviour, related to behaviour in general.[1] To be familiar with the reproductive and pheromonal behaviour of pest insect species, connected with locomotion and nutrition, has a special importance for the realization of monitoring and management programmes.

Reproduction and pheromonal behaviour analyzed under laboratory and field conditions (with special reference to *Mamestra brassicae* L.) has made possible to present the specific behavioural model. This is in fact a complex behaviour which implies reproduction, locomotion and nutrition, common and at the same time specific activities which are the part of the complex relationships with the environment and of the intra- and interspecific relationships (Fig. 1). They constitute together the ***reproduction-locomotion-nutrition syndrome***.

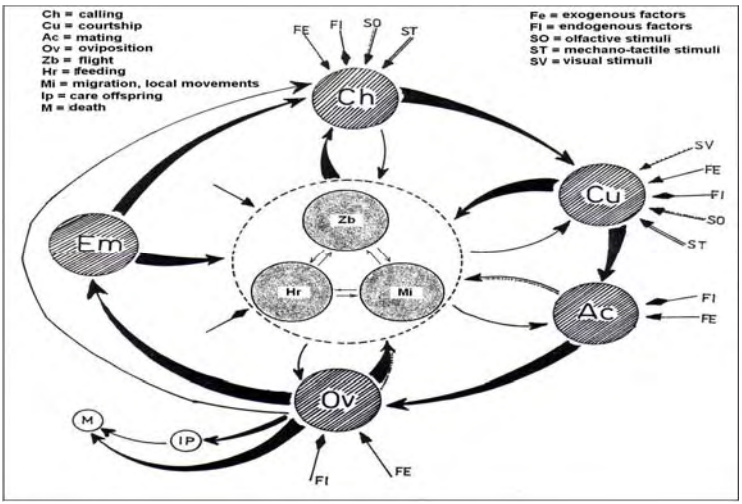

Fig. 1. The model showing the phases and sequences of the reproduction-locomotion-flight syndrome at insect species[2]

[1] Gheorghe Stan, "Comparative Studies on Reproductive Behaviour in Arctiidae and Noctuidae Moth Species (Lepidoptera). II. Male Behaviour in Female Locating, Courtship and Copulation", in *A IV-a Conferință Națională de Entomologie, 29–31 mai 1986 (IV*[th] *National Conference of Entomology: 29–31 May, 1986),* ed. Nicolae Tomescu (Cluj-Napoca, 1988): 361–371; Stan, "Reproductive Biology…", 87–133; Gheorghe Stan, "Pheromon-Forschungen in Siebenburgen", *Stapfia* 45 (1996): 221–258.

[2] Stan, "Pheromon-Forschungen in Siebenburgen", 221–258.

The complex study of behaviour by means of sexual pheromones and other stimuli has made possible the discovery of the specific behaviour of pest species in the field and implicitly the sensible use of chemical mediators in the control, monitoring, management and combating of target species. In the case of some species (for example *Mamestra brassicae, Ostrinia nubilalis*), initially we started from the observations that no correlations can be pointed out between the density of the species and the frequency of the attack on the specific culture plant which serves as a trophic basis,[1] showing a behaviour of "local migration" (a specific locomotor behaviour) (Fig. 2).

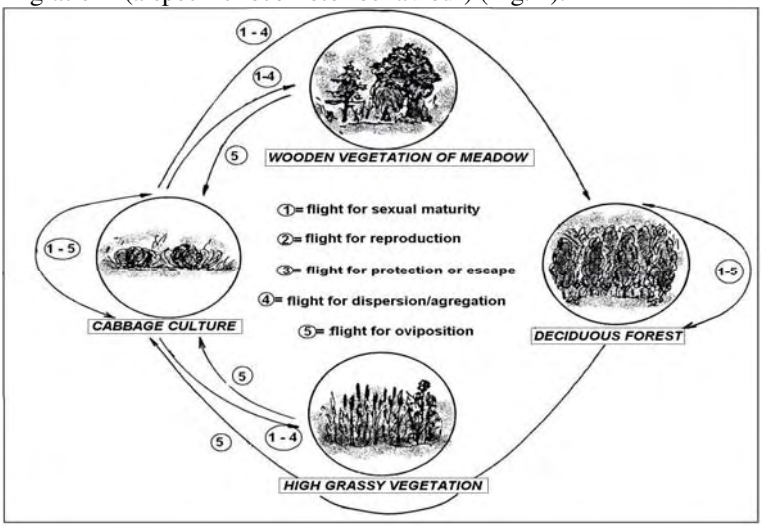

Fig. 2. The local movement of the species ***Mamestra brassicae*** *under natural condition. The model is based on the research made on the populations in the area of Cluj, 1980–1989*[2]

[1] Stan, "Pheromon-Forschungen in Siebenburgen", 221–258; Gheorghe Stan et al., "*Mamestra brassicae* L. (Lepidoptera: Noctuidae): Studies on the Larval Density and the Capture of Male Moths with Sex Attractant Traps in different Ecosystems", *Studia Universitatis Babeş-Bolyai*, *Biologia* 32 (1987), 2: 11–17; Gheorghe Stan et al., "Studies on *Mamestra brassicae* L. (Lepidoptera: Noctuidae) Behaviour and Dynamic of Populations in Natural and Agricultural Ecosystems, with both Light and sex Attractant Traps", *Buletin de Informare. Societatea Lepidopterologică Română (Informational Bulletin. The Romanian Lepidopterological Society)* 5 (1994), 1: 49–76.

[2] Stan, "Pheromon-Forschungen in Siebenburgen", 221–258; Gheorghe Stan et

For the practical actions of monitoring the species it is extremely important to be familiar with the periodicity of the behaviour. Each sequence, though genetically fixed for each sex, can be modified by the environmental factors. In the case of the *M. brassicae* too, for example, research has shown an earlier beginning of the sequential behaviour in correlation with temperature fall or the increase of age,[1] a phenomenon characteristic to other species as well.[2]

The study of the pheromonal behaviour under natural conditions. In this case there are two basic modalities: the method of traps and the method of behaviour observation. The special traps, in different forms and dimensions are tested in order to correspond to the species' flight behaviour and they are used differently depending on the aim of the investigations. Thus, in order to appreciate correctly the density, the relative size and the distribution model of the populations, a certain number of traps/experimental plots are necessary.[3]

The behavioural observations imply adequate mechanisms and equipments, and, by means of these, the flight model and the behavioural reaction to chemical mediators are visualized (Fig. 3).

The study of the specific activity period connected with the influence of ecological factors, the species' physiology and ecology and the arranging of the attractive and specific variants of chemical mediators made possible for us to point out the ***activity range of sexual pheromones***.[4]

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al., "Use of Sex Pheromones and Ecological Methods for Monitoring and Management of the *Mamestra brassicae* L. (Lepidoptera: Noctuidae)", *Studia Universitatis Vasile Goldiş, Stiinţele Vieţii* 12 (2002): 101–122.

[1] Stan, "Reproductive Biology…", 87–133; Stan, "Pheromon-Forschungen in Siebenburgen", 221–258.

[2] Kenneth F. Haynes, Martin C. Birch, "Mate-locating and Courtship Behaviours of the Artichoke Plume Moth *Platyptilia carduidactyla* (Lepidoptera: Pterophoridae)", *Environmental Entomology*, 13 (1984): 399–408.

[3] Gheorghe Stan, "Particularities of the Long Term…", 389–399.

[4] Stan et al., "Use of Sex Pheromones…", 101–122.

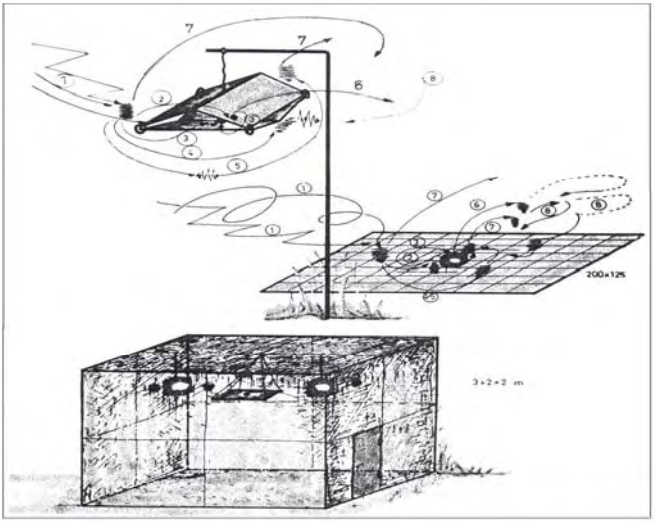

Fig. 3. The study of the specific behavioural answer to sexual pheromones under field conditions by using special cages and the platform to observe behaviour. The numbers refer to the behavioural phases, sequences and steps specific to the males of ***Mamestra brassicae***[1]

4. Sexual pheromones and the ecological study of pest insect populations

Chemical mediators proved to be extremely useful in demecological and synecological studies. Though natural pheromones have an intraspecific character, synthetic ones have interspecific features, this making possible the simultaneous characterization of sympatric species. We analyzed comparatively the response behaviour to different attractant stimuli, and sexual pheromones, for example, proved to be extremely efficient in the ecological characterization of field populations by means of some specific parameters.[2]

The analysis of the ***local population level*** by means of these parameters (index of overwintering, coefficient of generation, coefficient of variation, emergence model, regression) (Fig. 4) made possible to effectuate a complex analysis of the species' local population, to define a continuous r-K characteristic to the different areas and the fluctuations at

[1] According to Stan, "Pheromon-Forschungen in Siebenburgen", 221–258;
[2] Stan, Coroiu, Crişan, "Sex Pheromones Used in Ecological Studies…", 46–59.

the level of the populations according to which the managerial model was established.

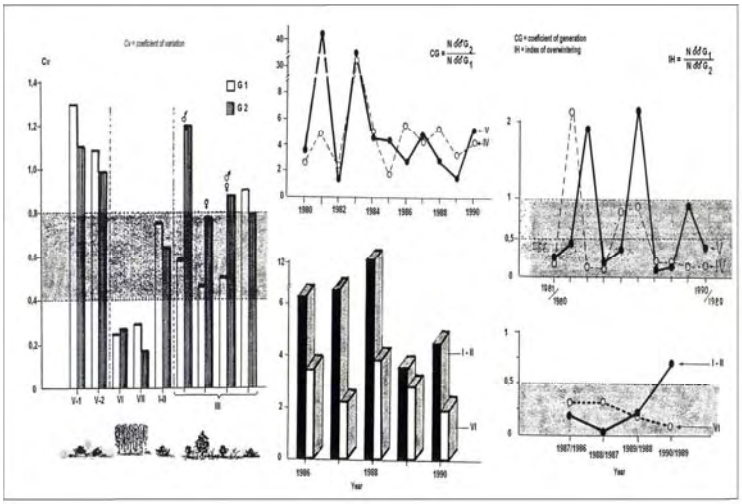

*Fig. 4. A model for analyzing the position of the **Mamestra brassicae** species at the level of a continuous r-K and the evolution of population levels in the area of Cluj by means of the index of overwintering (IH), the coefficient of generation (CG) and the coefficient of variation (Cv) in different types of ecosystems*[1]

By means of the specific synthetic sexual pheromone variants we analyzed with utmost correctness the populations' ***distribution (dispersion) model*** (Fig. 5), an aspect which must be taken into consideration in efficient monitoring and management.

The analysis of the ***emergence model*** (flight type)[2] offers indices regarding the way in which the methods for the supervision and control of the species are to be used, the general behaviour being anticipated and later on analyzed depending on the species' protogyny or protogamy.

[1] For the meaning of graphic representations see Stan et al. (1996).

[2] Stan, Coroiu, Crişan, "Sex Pheromones Used in Ecological Studies…", 46–59; Stan, "Ecological Management and Elaboration…", 381–388.

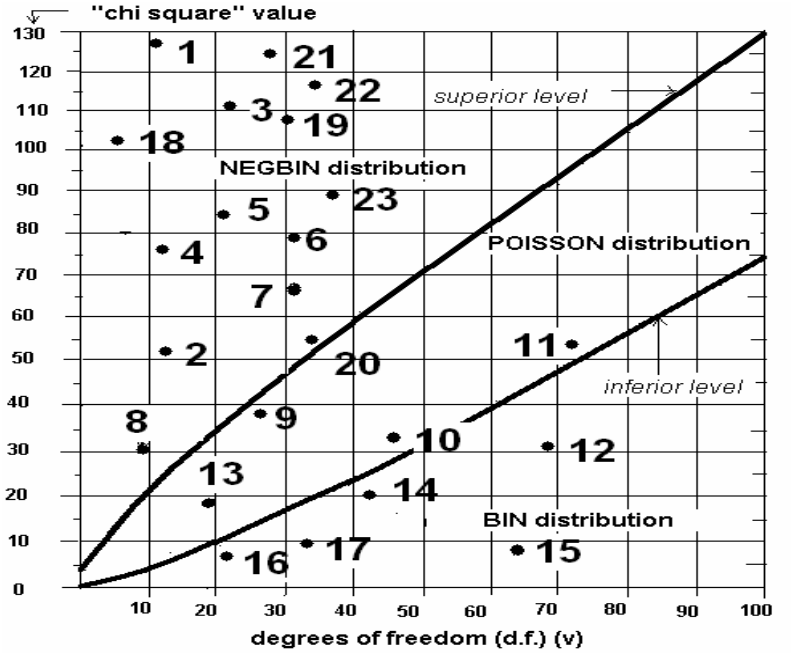

Fig. 5. The population distribution (dispersion) model of some sympatric Lepidoptera species in the area of Cluj elaborated on the basis of studies based on capture with pheromonal traps[1]

[1] According to Stan, "Semiochemicals – Behavioural Mediators…", 10–12. Based on Charles J. Krebs, *Ecological Methodology*, (California, New York: Addison Wesley Longman Inc., 1999): 580.

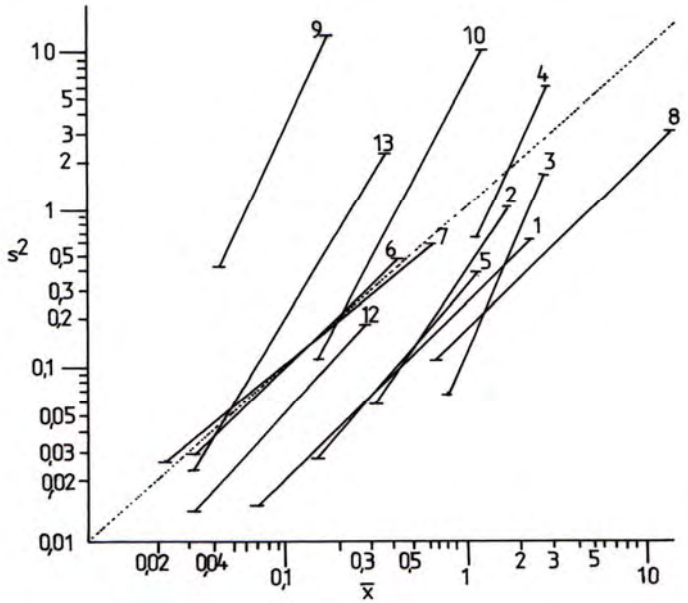

Fig. 6. The population distribution model of some constant and euconstant pest Lepidoptera species cohabitant with ***Mamestra brassicae*** *in the area of Arad (****Ostrinia nubilalis*** *– Lepidoptera: Pyralidae, it was included for comparison); 1 –* ***Lacanobia w-latinum; 2 – Ochropleura plecta (Cluj); 3 – Ochropleura plecta (Arad); 4 – Discestra trifolii; 5 – Mythimna pallens; 6 – Lacanobia w-latinum; 7 – Agrochola circellaris; 8 – Plutella xylostella; 9 – Ostrinia nubilalis; 10 – Lacanobia oleracea; 12 – Apamea monoglypha; 13 – Lacanobia suasa*** *(s^2 = variant (dispersion); x = avarage)*

It is important to be familiar with the distribution model in order to characterize the structure and to register the dynamics. Moreover, a correctly outlined specific model offers information on the size of the population and implicitly on the way in which capture techniques can be used (sampling). This proved to be even more important in the case of pest species, since it makes possible the correct placing of traps (orientation, distance, number of traps/area unit, etc.) and therefore it enables correct monitoring and the registration of the size of the population as near to reality as possible.

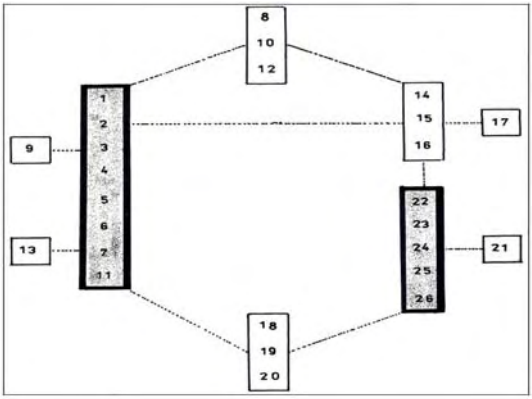

Fig. 7. The model of affinity established by means of the recurrent group method, based on the capture data of 27 Lepidoptera Noctuidae species – captured with pheromonal traps – included in the attraction spectrum of the Z11-16:Ac based variants[1]

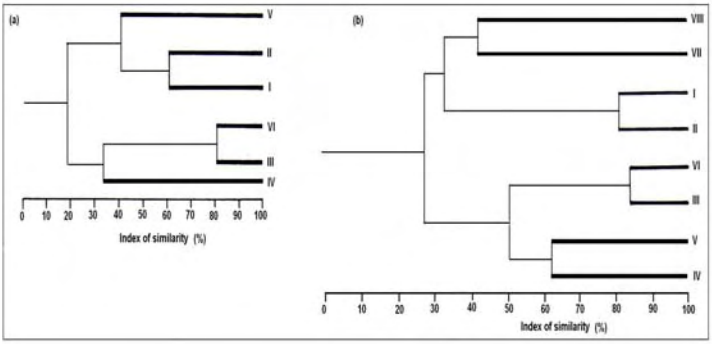

Fig. 8. The dendogram of similarity for 6 types of habitats and ecosystems in the area of Cluj (a) and 8 habitats in the area of Oraviţa (b), elaborated on the basis of 12 species of sympatric pest or potentially pest Lepidoptera Noctuidae (I – grasslands; II – cultures of vegetable; III – deciduous forests; IV – shrubs; V – cereal cultures, monocultures; VI – river meadows, grassy and woody vegetation of damp meadows; VII – orchards; VIII – gardens in settlements)[2]

[1] According to Stan "Semiochemicals – Behavioural Mediators…", 10–12. For further details see Gheorghe Stan, Lidia M. Pop, "Attractivity of the Pheromonal Variants with (Z)-11-Hexadecenyl Acetate for Some Lepidoptera Males", *Buletin de Informare. Societatea Lepidopterologică Română* 10 (1992), 2: 10–15.

[2] Stan, "Pheromon-Forschungen in Siebenburgen", 221–258; According to Stan, "Semiochemicals – Behavioural Mediators…", 10–12.

The data obtained on the populations of some pest Lepidoptera Noctuidae (in the area of Arad) highlighted different models of distribution for different species, and similar ones for the same species.[1] The illustration of the distribution model based on the T'sPL relationship (the correlation between dispersion and the average of daily capture) (Fig. 7) reveals these same aspects.

The study of ***affinity and similarity*** pointed out the relationship between some sympatric local species or between the affected biotic environments (Fig. 7, 8).

To estimate the biodiversity characteristic to a certain area implies a correctly monitored biologic material, only in this case can biodiversity be highlighted at the level of different habitats (Fig. 9).

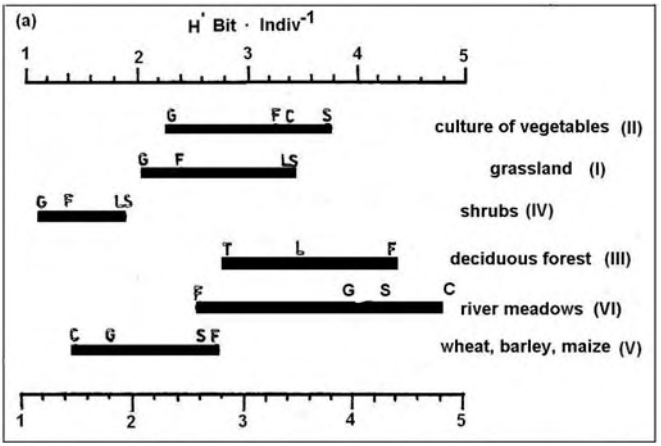

Fig. 9. The analysis of the biodiversity of the Lepidoptera Noctuidae fauna at the level of different ecosystem types. Study in the area of Cluj by means of analysis with the Shanon-Weaver index (the habitat numbers are the same as in Fig. 8; the letters signify the area of different stationaries)[2]

The synthetic sexual pheromones proved to be exceedingly efficient in studying **population dynamics**. The evolution in time of the population density of a target species offered precise information in

[1] Stan, "Particularities of the Long Term…", 389–399.

[2] Stan, "Pheromon-Forschungen in Siebenburgen", 221–258; Stan, "Particularities of the Long Term…", 389–399; Stan, "Semiochemicals – Behavioural Mediators…", 10–12.

monitoring and management operations, and, in many cases, pheromonal traps proved to be more exact than other models (Fig. 10).

Population dynamics must be understood as an "etiological phase" within general behaviour, related to adults' local movements or migration, alternating aggregation with dispersion, emigration with immigration and everything systematically influenced by ecological factors.

5. The use of sexual pheromones in ecological monitoring

The complex aspects related to the integrated management of pests appear implicitly associated with the environmental issue. Any human intervention in agriculture aimed at the control and combating of pests may cause serious changes in agroecosystems and also in nearby natural ecosystems and it may greatly affect the environment or even society.[1]

The specialists of this domain consider that monitoring is an "action" and a part of management, considered a "conception". In the field of pests integrated management implies the selection, the integration and the application of pest control methods "based on economic, ecologic foresight and sociological consequences".[2]

[1] Pimentel, *Environmental Aspects…,* 185–201.

[2] Dale R. Bottrell, *Integrated Pest Management* (Washington: Council on Environmental Quality, 1979), 120; Barbara A. Croft, "Apple Pest Management", in Robert L. Metcalf and William H. Luckmann, *Introduction to Insect Pest Management*, (New York: John Wiley & Sons Publishers, 1982), 577.

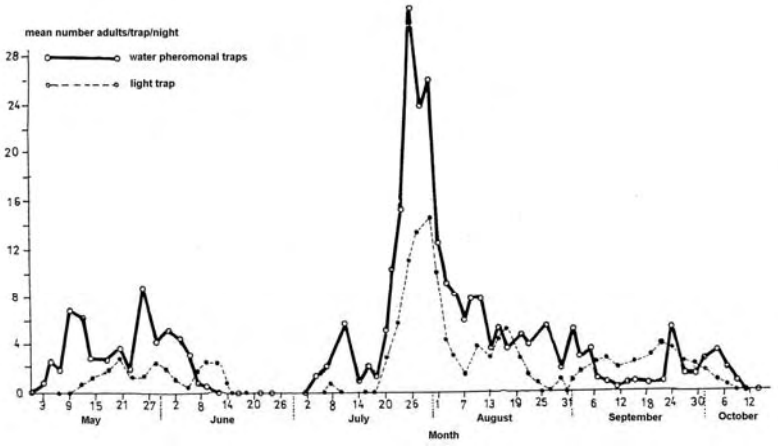

Fig. 10. Model showing the flight curves of adult Xestia c-nigrum specimens, elaborated on the basis of capture data obtained by means of pheromonal and light traps. Cluj, 1989.

Long-term monitoring. The flight curves were drawn based on these data and they were analyzed by means of the regression equation for the populations' evolutionary tendency. In order to highlight the importance of long-term monitoring, the general form of the regression line, which was obtained each year, and through which the structure of the local population was marked on the basis of the linear model,[1] was compared with the trend of regression lines obtained at different intervals. The regression equations evaluated on the basis of the average number of adults/traps/day/year, are also presented here for different intervals, cumulating the values for the two generations. The correlation coefficient (**r**) of the regression equations showed the extent of the relationship between the variables.

Systematic and long-term monitoring offered significant information referring to the ecology and behaviour of the *Mamestra brassicae* species, but also to other cohabitant or sympatric Lepidoptera species.

[1] David G. Butler Jr., Robert T. Pfrimmer, John W. Davis, "A Model to Describe the Uniform Build-up of Populations of Adult Bollworms and Cabbage Loopers", *Environmental Entomology* 3 (1974), 6: 978–980.

Long-term monitoring led to the observation that some species considered to have an extremely reduced population level (some of them considered rare), have a particular population dynamics in reality, being highlighted that the level is periodically restored.

Our data referring to the state of the local population, at that time, but in the same area, highlighted a variation in the increase rate (illustrated by the variable values of **b** as well as by the values of the **r** correlation coefficient), with differences depending on the trap and the ecosystem (Table 1). Comparing the data of the two tables a relative similarity can be observed between the values of the regression equation parameters, which show relatively close dimensions for the male populations captured by pheromonal traps (in a wood situated in the neighbourhood of a specific trophic basis culture – cabbage) and the female populations caught by light traps placed in the cabbage culture.

Table 1. The regression equations* of the linear model of *Mamestra brassicae* populations (Cluj, Florești area; 1990–1999), evaluated on the basis of the capture data of pheromonal traps

Year	No. year	No. obs.	a		b		r	
			NE	AE	NE	AE	NE	AE
1980	1	52	3.0424	-0.4812	0.6628	0.1256	0.5724	0.8214
1981	2	54	-0.9012	-0.1834	0.4741	0.0882	0.7854	0.7234
1982	3	64	1.1412	0.7621	0.6242	0.0246	0.6236	0.6458
1983	4	66	-5.9212	0.4212	2.7841	0.0672	0.3418	0.5682
1984	5	58	0.1422	0.2235	0.1349	0.0827	0.7418	0.8120
1985	6	58	3.4250	0.1834	0.1524	0.1235	0.6081	0.7224
1986	7	68	-0.8941	-0.0245	1.2943	0.0942	0.3921	0.5846
1987	8	66	1.9422	-0.1221	1.2874	0.0546	0.4134	0.4892
1988	9	62	-4.2213	1.2456	2.4627	0.1120	0.3488	0.7533
1989	10	52	1.7413	0.1385	1.3204	0.0444	0.3081	0.6228
1990	11	58	1.1418	0.1182	0.6421	0.1260	0.5822	0.8234
1991	12	64	3.2174	0.0687	0.8004	0.0555	0.5244	0.5822
1992	13	64	-0.8744	-0.1289	0.3212	0.0122	0.3346	0.4671
1993	14	59	1.0864	-0.0888	3.2412	1.1004	0.6812	0.7321
1994	15	63	3.3432	1.2102	0.1418	0.8422	0.3821	0.6004
1995	16	66	0.1458	1.7602	1.2888	0.0121	0.5812	0.4826
1996	17	55	-0.2436	-3.1204	0.9886	0.7666	0.6614	0.7668
1997	18	58	2,2424	-0.0231	2.9884	0.9812	0.3289	0.6213
1998	19	64	1,8924	0.4612	1.3227	0.1400	0.7812	0.4688
1999	20	60	-3,2876	0.1209	1.7052	0.5428	0.3626	0.7812

* regression equiation: y=a+bx (y = the number of captured males; x = capture values for the interval 1–2 days, yearly, for the period 1 May–5 September; a, b – constants); NE – natural ecosystem (deciduous forest); AE – agricultural ecosystem (vegetable cultures, including *Brassica oleracea*); r = correlation coefficient

Previously obtained data are analyzed and new data, obtained specifically on *Mamestra brassicae* L. are presented to highlight the importance of long-term eto-ecological research with regard to get thorough knowledge on the species. 10 other constant and euconstant Lepidoptera species are also referred to (from a whole of 78 species captured by pheromonal traps with variants based on Z11-16:Ac and present in the light traps)[1]: *Lacanobia oleracea* L.*, Lacanobia suasa* Den. & Schiff.*, Lacanobia contigua* Den. & Schiff., *Lacanobia w-latinum* Hufn., *Discestra trifolii* Hufn.*, Ochropleura plecta* L.*, Apamea monoglypha* Hufn.*, Mythimna pallens* L., *Agrochola circellaris* Hufn., *Plutella xylostella* L.

The linear model of population dynamics. The representation of *Mamestra brassicae* population dynamics by means of flight curves obtained on the basis of captures clearly showed the significantly greater abundance of males in the pheromonal traps placed in natural ecosystems and the greater frequency of females in the light traps in agroecosystems. The trend of flight curves is typical for this species and has been described in detail.[2] Other data refer to the research of the population dynamics of several Lepidoptera Noctuidae species, based on the capture data of light traps.[3]

With reference to the *Mamestra brassicae* species it must be said that the dynamics of the species was studied by monitoring in different ecosystems and habitats, according to the behavioural model characteristic to this species and shown both in the area of Cluj[4] and of Arad. The phenomenon of "local migration" is associated with protogyny, polyphagia, pheromonal and reproductive behaviour, kairmonal behaviour, ecological factors, aggregation or dispersion in the case of this species.

For other sympatric or cohabitant species different results were obtained, depending on the relationship with the host plant, on the aggregation or dispersion behaviour, the level of the local population, and the response behaviour of the two sexes to the attractant stimuli used for capturing as well. Thus, for *Lacanobia oleracea*, a species considered harmful for crucifers, the linear model was different, the trend of the two regression lines being relatively uniform after 10 years of monitoring. In other words, in the case of this species, 10 years monitoring was

[1] Stan, Pop, "Attractivity of the Pheromonal Variants...", 10–15.
[2] Stan et al., "Studies on *Mamestra brassicae* L. …", 49–76.
[3] Stan, Coroiu, Crişan, "Sex Pheromones used in Ecological Studies…", 46–59;
[4] Stan, "Reproductive Biology…", 87–133.

sufficient for "optimal information", and for shorter intervals we obtained different models. From this point of view one can practically observe the grouping of species, correlated to the size of the local population and the preference for a certain habitat. There is, in fact, a rational way of exploiting the environment, a "complementarity mechanism" according to which the daily or seasonal activity or population level is regulated.[1]

Correct as a monitoring might be – mainly in the case of insects –, only the relative dimensions of the local population can be estimated after all. The composition of adult captures varied according to the type and placement of traps, and also depending on the reaction behaviour to the action of the attractant stimulus. In the light trap both sexes were captured, but the relation was extremely varied from species to species.[2]

The equation of the central tendency of the population level evolution. The abundance of local population varied from generation to generation and from year to year (sometimes significantly; D'sNMRT; P=0.05), the trend of regression lines showed, in each case (mainly when the population level was higher), a tendency of growth in the local population level in G_2 compared with G_1.

[1] Gheorghe Stan, Ioan Coroiu, "Dynamics of Soil Collembola Populations (Insecta, Apterygota) under Alfalfa Culture, in the Someş Valley (Cluj Department)", *Travaux du Museum d'Histoire Naturelle "Grigore Antipa"* 19 (1978): 279–283.

[2] Stan, Coroiu, Crişan, "Sex Pheromones used in Ecological Studies…", 46–59.

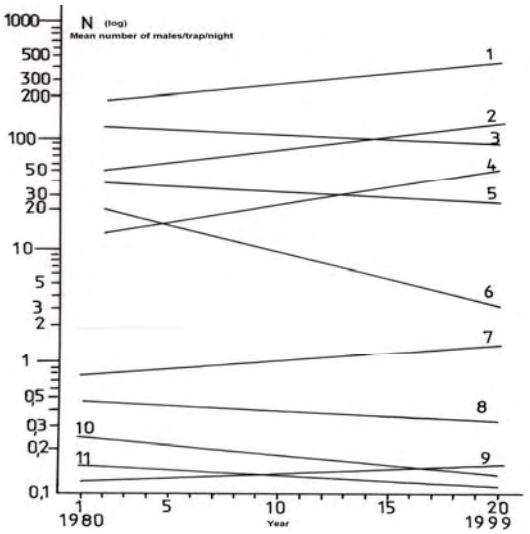

Fig. 11. The populations' evolutional tendency and their local level for a period of 20 years in the area Cluj–Floreşti in the case of ***Mamestra brassicae*** *and other 10 (constant and euconstant) cohabitant species (1 –* ***Plutella xylostella****; 2 –* ***Ochropleura plecta****; 3 –* ***Discestra trifolii****; 4 –* ***Lacanobia oleracea****; 5 –* ***Lacanobia suasa****; 6 –* ***Mythimna pallens****; 7 –* ***Mamestra brassicae****; 8 –* ***Lacanobia contigua****; 9 –* ***Apamea monoglypha****; 10 –* ***Lacanobia w-latinum****; 11 –* ***Agrochola circellaris****). The estimation of the evolution tendency in time of the populations of 10* ***Lepidoptera Noctuidae*** *species (constant and euconstant) cohabitants with* ***Mamestra brassicae*** *in the area of Cluj, based on the capture data obtained in long-term monitoring (we start with the consideration that the permanent captures associated with different methodologies of combating could lead to the disappearance of some species; data show that this does not happen in the case of r-strategist pest species, the tendency being the maintaining or even a slight increase of the level; the regression line can give predictive information for a certain period; the trend was decreasing only for K-strategists).*[1]

[1] Gheorghe Stan, "Male Response Behaviour to Semiochemicals of Some Moth Species (Lepidoptera: Noctuidae) under Laboratory Conditions. 1. Method of Bioassay, Response Estimate and Relative Importance of Quality Response to Natural and Synthetic Sex Pheromone in Conditions in *Mamestra brassicae* L. and *Xestia c-nigrum* L. (Lepidoptera: Noctuidae)", *Buletin de Informare. Societatea Lepidopterologică Română* 4 (1993) (1): 31–43; Stan, "Particularities of the Long Term…", 389–399.

The representation of the regression lines illustrating the evolution tendency of the local *Mamestra brassicae* population, for example, for the captures with same type of trap, and the processing of the data for different periods from the 20 years long monitoring duration have showed little differences in their trend (in the case of the 10–20 years long sampling periods), or the trend was relatively close (for periods of 5 years). This species has in general a reduced constant local population level, but a shorter monitoring (3–5 years) presented another evolution tendency for them.[1] On the other hand, in the case of *Lacanobia oleracea, L. suasa, Discestra trifolii* and *Ochropleura plecta* there were no differences in a 10–20 years interval, but shorter monitoring intervals do not indicate a real estimation of either population size or population evolution tendency. Otherwise, the models varied according to the evolution of local population level in the case of the 10 constant and euconstant species (Fig. 11).

It is evident that, due to our point of view (the management of pest insect species), we were only interested in species with an economic value, but the method itself can be applied for ecologic purposes as well, mainly in studies made on useful or disappearing rare species. It has been stated that the term "rare species" tends to change its content radically by the use of a systematic and long-term monitoring.

There are few such studies and, in the case of some species, even abundance remains at close values, there being no great differences regarding the yearly level of the local population and existing a great similarity in the population increase rate from a year to the other (for periods of 7–13 years).[2]

Capture data and the specific homing. With regard to the preferential habitat (homing) of adults, the life conditions offered by this are extremely important. In the case of a natural ecosystem (forest), and other characteristic habitats as well (e.g. woody and herbaceous vegetal formations characteristic to riversides) it offers optimal conditions of life (reduced insolation, high humidity, lack of chemical treatments, low level of the specific pest population etc.).

In the case of typical pest species, the preferential host plant and the chemical mediators (pheromone, kairomone and synomone types) regulate the intra- and interspecific actions, as well as the evolution of the population levels. In the case of the *Mamestra brassicae* species, the

[1] Stan et al., "Studies on *Mamestra brassicae* L. …", 49–76; Stan, "Particularities of the Long …", 389–399.
[2] Butler, Pfrimmer, Davis, "A Model to Describe the Uniform…", 978–980.

Brassica oleracea constitutes the preferential food type, and it has been shown that the behavioural model of the two sexes depends on this and, implicitly, on the reproduction and flight behaviour.[1] (See Fig. 2.)

The use of the line-transect method has shown that males prefer certain biotope types (Fig. 12).

In monitoring research a series of trap techniques and types can be used according to the specie's biology and behaviour or the phenology of the host plant, being possible to choose the most efficient variant.[2] Pheromonal traps capture only males, but, supposing that the rate of the sexes oscillates approx. 1:1, estimations can be relatively correct. On the other hand, in the case of those species where the trophic basis of larvae and adults is not known and where the adults and larvae have different habitat preferences, this kind of research can constitute a qualitative and quantitative prognosis source in the respective area.[3]

[1] Stan et al., "Studies on *Mamestra brassicae* L. …", 49–76.

[2] Williams T. Sappington, Williams B. Showers, "Comparison of Three Sampling Methods for Monitoring Adult European Corn Borer (Lepidoptera: Pyralidae) Population Trends", *Journal of Economic Entomology* 76 (1983): 1291–1297.

[3] Butler, Pfrimmer, Davis, "A Model to Describe the Uniform…", 978–980; Helmuth Riedl, "Monitoring and Forecasting Methods for Codling Moth Management in the United States and Canada", *EPPO Bulletin* 10 (1980), 2: 241–252; Stan et al., "*Mamestra brassicae* L. (Lepidoptera: Noctuidae): Studies on the Larval Density…", 11–17.

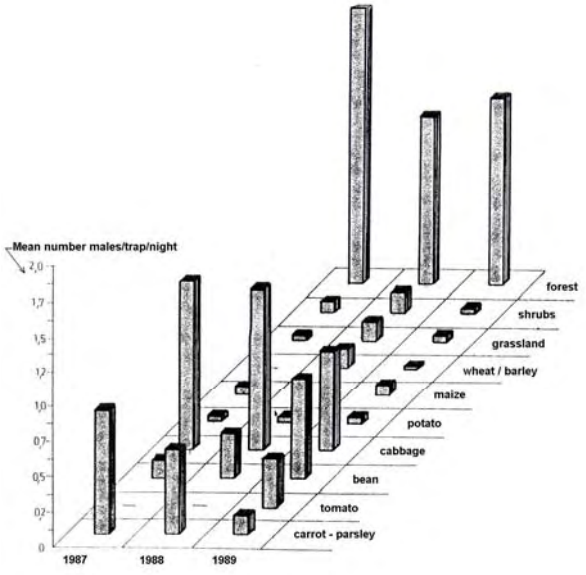

Fig. 12. The preference of adults for certain biotope types. The size of the male ***Mamestra brassicae*** *population captured by the pheromonal traps placed in the line-transect method. The area of Cluj, 1987–1989*[1]

6. The use of sexual pheromones in the ecological management of pest populations

We present here some results referring to the model of management decision at the *Mamestra brassicae* species, based on the correlating of the information obtained by means of long-term monitoring of adults (with pheromonal and light traps) and of larvae (by different sampling methods) in the area of Cluj. On the basis of the initially elaborated model we make a series of commentaries which reveal the necessity to continue the investigations and to complete the specific model based on the information suggested by a general theoretic model.

Nowadays, ecologic pest management has become a strategy, an attitude, a real science. We no longer speak of "adding and trying" new methods, but of scientific research on the specific biology, ecology and behaviour. The use of chemical mediators in monitoring and

[1] Stan et al., "Studies on *Mamestra brassicae* L. …", 49–76.

management constitutes an efficient, economically profitable modality with many advantages in the field of science, but a modern view is necessary in their acceptance[1] and the involvement of the decision making political factors.[2]

Management decision. Based on the long-term (20 years) monitoring of the *Mamestra brassicae* species, an important pest of crucifers (especially *Brassica oleracea*) a management decision has been elaborated following the modern concepts of ecological management of pest insect species.

The model of a managerial decision for *Mamestra brassicae*[3] was realized on the basis of some long studies, starting with the relationship between the adult population level and damage, to the combination of biotechnical control methodology with chemical methods trying to reduce significantly the chemical treatments without affecting other components of the biocenosis, and to keep the pest population under a harm threshold without affecting the relationship between the trophic levels of ecosystems. The model used by practitioners has enabled the reduction of the number of chemical treatments from 4-5 to a single one without affecting the quality of the culture plant.[4]

New concepts in the domain imposed new research modalities as well. A new terminology has appeared which is adequate to the new orientations of environmental protection (***ecological pest management, intelligent plant management, integrated culture and pest management, integrated protection, epharmony***),[5] the role of ecology in the restoration of ecosystems being emphasized. ***Integrated pest management*** has been defined as "*a managerial system of a pest population which uses every possible technique in a compatible manner to reduce pest populations and to keep them under a level which would cause economic damage*".[6]

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[1] Mitchell, "Pheromones: as the Glamour…", 132–139.

[2] David A. Lindquist, "Social and Economic Aspects of Alternative Insect Control Methods" *Pesticide Science* 8 (1987): 389–393.

[3] Gheorghe Stan, Mihaela A. Nicolescu, "The Management Decision for Pest Insects. One Case Studies: ***Mamestra brassicae*** *l. (Lepidoptera: Noctuidae)*", *Studii şi Cercetări (Siinţele Naturii)(Studies and Research, Natural Sciences)* 4 (1998): 273–284.

[4] Stan, "Particularities of the Long Term…", 389–399.

[5] Author cited in: Ibid., 389–399.

[6] Author cited by Charles H. Wearing, "Evaluating the IPM Implementation Process", *Annual Review of Entomology* 33 (1988): 17–38.

Elaborating a management decision for pest insect species requires a great amount of study and research.[1] It is obvious that the substitution of the term (biologic, biotechnical or genetic) combating for ecologic management implies a conceptual reorientation. Thus, any pest becomes an essential link in a trophic chain or network and should not be removed, but maintained as a population level under a balanced damage and intervention threshold (by means or one or several complementary methods), in order to diminish the population level. Therefore, the importance of a systematic and long-term scientific monitoring occurs here too.

Monitoring implicitly offers better knowledge of the species as well, which will lead to the selection of a certain managerial methodology for the control of the species. The necessity to protect the environment, to obtain healthy, unpolluted agricultural products, to preserve the health of biocenoses and, evidently, of man extended the use of the adequate methodologies of biological, genetic and especially biotechnical combating. Within integrated combating conventional methods (of physical and chemical agricultural practice) cannot be given up as yet, but lately a new line has been followed in this domain.

By means of a linear model, on the basis of the regression line and equations we established the moment when the monitoring and the controlled intervention – with a method based on biological or biotechnical procedures – on the species is to be started. During the elaboration of the management decision and mainly in order to fix the moment of the application and the number of treatments, we have once again found a mathematical method for the processing of data.[2] The sequential plan, which determined the 3 areas by 2 regression lines, was elaborated on the basis of the relationship between capture and larva and egg population by means of a sequential decisional sampling resulted from the combination of systematic and aleatory sampling. The upper regression line delimited the area where the treatment was applied or continued; the lower regression line delimited the territory free of intervention; the line showing the continuation of sampling is between them.

The monitoring decision is based on the correlation between the capture of adults, the frequency of oviposition, the frequency of larvae

[1] Peter D. Lingren, George L. Green, "Suppression and Management of Cabbage Looper Populations", *USDA Technical Bulletin* 1684 (1984): 152.

[2] Stan, Nicolescu, "The Management Decision…", 273–284; Stan, "Ecological Management and Elaboration…", 381–388.

attack and damage, determined by systematic research in the characteristic ecosystems in which the different behavioural sequences of the species take place.

7. The use of pheromones in the direct control of the population level

The natural stability of an ecosystem and the low density of the pest population level are maintained by the application of some combating principles. Such a program has at least four important stages: 1) systematic monitoring with chemical mediators or other methods which take into consideration the specific behaviour; 2) recording some evident or significant modifications in the abundance of the local population; 3) the correlation of adult captures with the size of the egg and larva populations; 4) studying the abundance and highlighting the relative size of the populations and their evolutionary tendency.

Direct combating programs (especially by ***mass captures***) have gradually lost their importance having been substituted by managerial programs. The application of some methods of massive eradication, which could affect useful species as well, unbalances the functionality of ecosystems by the modification of intra- and interspecific relationships.

Compared with mass capture, which requires great economic effort, the program of ***disorientation*** by means of sexual pheromones proved more profitable. Because of their specificity, these pheromones do not affect other species and the disorientation program itself, by diffusing a great amount of pheromones in the area with the target species. They prevent the males from orienting towards the conspecific females, the frequency of mating decreases, and the population level is reduced to a minimal threshold which no longer affects the host plant.

The studies we made revealed promising results for some pest *Lepidoptera Noctuidae* species (Fig. 13).

Conclusions

The presented data are only a part of the results obtained by the author in the course of some long-term studies made in the domain of pest insects' reproductive and pheromonal behaviour. Chemical mediators and among them sexual pheromones offer manifold advantages from the point of view of application, affecting the environment beneficially.

Systematic and long-term monitoring offered significant information referring to the ecology and behaviour of the *Mamestra brassicae* species and to other cohabitant or sympatric Lepidoptera

species as well. The attraction range of Z11-16:Ac based pheromonal variants, including 78 Lepidoptera species highlighted the interspecific character of the sexual pheromone and edified a great number of cohabitant species with preferences for certain types of habitats, 10 species being constant and euconstant in the habitats where *Mamestra brassicae* were also captured. We were able to define the final structure of the communities in the area only by long-term monitoring, some species being present only at great intervals of time, and the fact that they show affinity for the respective biocenosis or habitat was proved by the fact that the individuals were recaptured after a period of several years during which the species had not been signalled.

The precise elaboration, in the research phase, of the specific model (distribution, dynamics, population size, evolution tendency) during a permanent and long-term monitoring will make possible later the application of the operations characteristic to ecologic management and implicitly the progressive diminishing of excessive capture or direct combating operations.

On the basis of a long-term (20 years) monitoring of the *Mamestra brassicae* species, an important pest of crucifers (especially *Brassica oleracea*) a management decision has been elaborated following the modern concepts of ecological management of pest insect species.

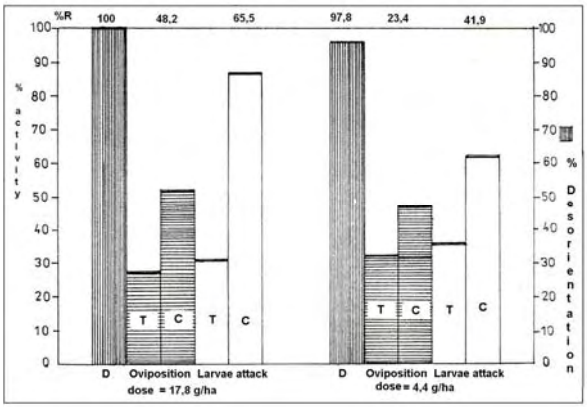

Fig. 13. The efficiency of the direct combating method by disorientation with 2 doses of synthetic sexual pheromones for the ***Xestia c-nigrum*** *species [T=treatment; C=control (witness); D=% disorientation]*[1]

[1] According to: Stan, "Ecological Management and Elaboration…", 381–388.

The elaboration of this decision implies thorough knowledge of the target species' biology, ecology and behaviour.

By means of a linear model, on the basis of the regression line and equations, we established the moment when the monitoring and the controlled intervention – with a method based on biological or biotechnical procedures – on the species is to be started.

The monitoring decision was based on the correlation between the capture of adults, the frequency of oviposition, the frequency of larvae attack and damage, determined by systematic research in the characteristic ecosystems in which the different behavioural sequences of the species take place.

The practical experimenting with the model made possible the application of a single treatment instead of the 4-5 frequently used procedures in the case of *Mamestra brassicae* in cabbage culture.

Our investigations showed that sexual pheromones can be an efficient and advantageous modality in the study of biocenoses, ensuring the maintenance of the equilibrium between the involved trophic levels and, at the same time, the ecological protection of the ecosystems, favouring ecological agriculture at the level of agroecosystems.

Translated by Ágnes Korondi