GUEST EDITORIAL

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Conservation and Enhancement of Natural Enemies in Biological Control

Conservation and enhancement of natural enemies of agricultural pests deal with indigenous and imported species. In general, beneficial arthropods suffer largely from inappropriate conditions during the plant growth and hibernation periods. By providing proper environments, beneficials may be preserved and enhanced. To achieve this, several measures can be utilized.

During the plant growth period natural enemies are basically affected by application of pesticides, lack or destruction of proper food resources and devastation of natural environments.

Pesticides used in agriculture not only kill target pests but also eradicate natural enemies to a great extent. Furthermore, entomophagous insects suffer indirectly from the loss of prey or specific hosts. An essential keystone for the enhancement of beneficials is the renunciation of broad-spectrum pesticides, and the targeted application of insecticides and acaricides. The use of selective, specific and safe-to-beneficials pesticides may contribute much to achieve this objective. Today, even the plant protection industry exerts increasing efforts for developing safe-to-beneficials products. In some European countries, *e.g.* Germany, each pesticide container bears a declaration specifying the beneficial-safety-status of the product. In many cases, the exact timing of pesticide applications is achieved by predicting the occurrence and population development of pests. These forecast systems place special emphasis on consideration of the economic threshold of each pest. The latter point is also an essential requirement of integrated pest management programs. In that way, the number of pesticide applications will be reduced; thus, as a consequence, natural enemies will benefit. Several studies indicated that also reduction of the active substance applied will not diminish the control efficacy due to increasing preservation of natural enemies (2). The infestation of agricultural crops by insect pests is often concentrated along field margins or clustered within the field. In such cases, if only parts of the field are treated not only will the profitability of the application be increased but natural enemies will be allowed to move to untreated areas. In addition, the use of 'alternative' pesticides such as plant constituents or commercially available *B.t.*, virus and fungus products will contribute much to the conservation of natural enemies. However, it should be remembered that the use of such products is not without risk, since many plant constituents are very toxic and entomopathogens may affect an exceptionally broad range of host organisms. Thus, a careful risk assessment is essential to avoid hazardous effects, as known for conventional pesticides.

Cultivated land is characterized by the occurrence of only a few insect species but these being very abundant. Pesticide applications in combination with several specific crop management measurements in high input crops strongly minimize the potential benefit that natural enemies may provide. Experience, however, shows that the specific requirements of beneficial arthropods can be satisfied by applying simple cultural measurements, without any adverse effect on extensive agricultural practice.

Conservation and establishment of natural habitats and refuges play therefore an essential role in the encouragement and enhancement of natural enemies. In this context, especially hedges provide important refuges for predators and parasitoids of many pest species, where they find safe shelters and alternative prey and hosts in case of food scarcity in cultivated fields (5). At such sites long-lasting and self-regulating biocoenosis will be established. Also field balks are considered as important ecological compensation zones, *e.g.* as reservoirs for aphids and their natural enemies (10). A higher acceptance of weeds in agricultural crops may increase the efficacy of natural enemies. Optimized micro-climatic environments can be achieved by several cultural measurements. In hot-arid areas, trees will provide shade and thus, suitable climatic conditions for beneficial arthropods. By applying this simple technique, *Trisolcus vasilievi* (Mayr) and *T. semistriatus* Nees, important egg-parasitoids of the sunn-pest, *Eurygaster integriceps* Put., could be conserved in Turkey (9).

After establishing a program in Germany and other European countries focusing on the creation of artificial, and the preservation of naturally, occurring weed strips along or within fields, it was shown that they substantially increased the insect species diversity and the number of predators and parasitoids. As exemplified in many experiments, it is also possible to make direct use of weeds in arable land to enhance beneficial arthropods. In particular, nectar-producing plants like Umbelliferae, *Phacelia tanacetifolia*, mustard, etc., provide important food resources for predators and parasitoids like tachinids and syrphids. For example, the targeted sowing of *Phacelia* sp. in wheat fields led to an increasing number of several polyphagous predator species like syrphids, which resulted in a subsequent only weak infestation with grain aphids (3). Some authors even recommend to establish weed strips in the center of fields (4).

A proper environment to enhance mono- and polyphagous beneficials can also be achieved by intercropping bromegrass in winter wheat or, similarly, by keeping a constant green underground crop in fruit- and viticulture. Due to the good results obtained in

Russia, buckwheat and mustard can be recommended as undersown crops in fruit orchards (6). Substantial improvements could also be realized by strip cutting of alfalfa, as is common practice in California. This technique allows mobile beneficials to escape from the harvester and settle again in the remaining strip that still provides shelter and food. Similar effects will be accomplished in intercropping systems. We should, however, be aware that our knowledge on ecology is too limited to predict what happens when a certain measure is applied, since for nearly every example of success there is another example of a terrible failure.

At first sight, the increase or contribution of primary, secondary or alternative hosts of beneficials in plant protection appears to be a paradox. In fact, however, it was frequently shown that the constant maintenance of a sufficiently high population of a specific entomophagous insect depends strongly on the occurrence of pests at certain and critical periods. A classical example is the black scale, *Saissetia oleae* (Oliv.), that interrupts its development for a short period during summer in the hot-arid areas of central California. Planting of irrigated oleander plants adjacent to citrus orchards will allow continuous development of the black scale. As a result, the specific parasitoid *Metaphycus helvolus* (Comp.) becomes capable of reproducing and, thus, maintaining its population, especially during the hot summer months (1,6). Even the release of insect pests during such critical periods may be a convenient technique. This was proven in several experiments, *e.g.* releasing the red mite *Tetranychus urticae* Koch for the establishment of the predatory mite *Phytoseiulus persimilis* Athias-Henriot in protected cucumber and bean cultures (6), or releasing sterilized *Eupoecelia ambiguella* Hb. eggs between the two generations of this lepidopteran pest to preserve the egg parasitoid *Trichogramma semblidis* (Auriv.) in the Ahr valley in Germany (7). For example, the preservation of nettles, *Urtica* spp., important host plants of *Aglais urticae* L., will enhance the efficacy of *T. semblidis* against the second generation of *E. ambiguella*. This is because the parasitoid will maintain its population on this alternative host during the two non-overlapping generations of *E. ambiguella* (Ç. Şengonca and M. Schade, unpublished data).

During the hibernation period. Entomophagous insect populations that build up considerably high densities during the plant growth period, suffer from a lack of hibernation sites and inappropriate climatic conditions. This situation will lead to a drastic decrease in the abundance of natural enemies. The small and enfeebled overwintering population will have a slowed-down and delayed population buildup in the next spring that will allow unhampered development of plant pests.

By preserving existing natural hibernation sites, entomophagous insects can be preserved during overwintering. Stones provided at hibernation sites as hiding places for coccinellids substantially increase the number of surviving lady beetles. Felt belts wrapped around the trunk of vines and fruit trees will in the same way protect the predatory mite *Typhlodromus pyri* Scheuten. The green lacewing, *Chrysoperla carnea* (Stephens), hibernates as an adult under the bark of trees, in barns, houses, roof-trusses, etc., where mortality during winter may still reach 90%. In hibernation boxes designed especially for lacewing – the green lacewing chamber – the mortality is significantly reduced to only 4–8% (8). The green lacewing chamber is meanwhile used in several European countries and serves not only as an excellent hibernation site but, in addition, increases considerably the efficacy of lacewings in the subsequent spring.

Conclusion. Even though the conservation and enhancement in biological control programs offer several practical opportunities that have already showed promising results, very little has been invested in research on these problems. To make more widespread use of these methods available, research should focus not only on biosystematics, biology, ecology and efficacy of entomophagous insects but also put emphasis on basic studies of enhancement, hiding-places and hibernation sites. Further studies of these subjects appear to be a promising and advantageous assignment for plant protection specialists.

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