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# BIOLOGY OF CHRYSOPIDAE

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## 8.2. BIOLOGICAL CONTROL IN THE FIELD
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### 8.2.1. *Introduction*

Biological control as defined by DeBach (1964) includes basic studies, importation, population augmentation, and conservation of beneficial organisms to regulate population densities of other organisms. The term 'manipulation' has been used to describe special procedures that may be necessary to help a natural enemy become established or to become a more effective biological control agent; these procedures can involve manipulation of the natural enemy itself or manipulation of the environment (DeBach & Hagen 1964).

The biological control potential of certain members of the family Chrysopidae, particularly species in the genus *Chrysopa* s.l., has been evaluated in a large number of studies involving manipulation (Ridgway & Kinzer 1974; Shuvakhina 1974; New 1975b; Ridgway & Vinson 1977; Hagen & Bishop 1979; Abies *et al.* 1979). Chrysopids have received special attention in this regard because even though they are common and efficient predators, their numbers are often inadequate to provide the desired level of pest control. Extensive studies on their manipulation have been made possible by the availability of methods for rearing large numbers of chrysopids (see Chapter 8.1.) and of sources of food supplements and attractants (Hagen & Bishop 1979). Types of manipulations include studies of field releases, food supplements, attractants and interplanting of crops. We will discuss here the possible use of these manipulations to control pests on some vegetable, fruit and field crops, excluding those crops grown in glasshouses which are noted in Chapter 8.3.

### 8.2.2. *General considerations*

Efforts to increase the numbers of natural enemies through manipulation in the field to obtain practical pest control should be designed to complement naturally occurring populations of beneficial organisms. Therefore, a knowledge of the population dynamics of all natural enemies of the pest is desirable; likewise, a knowledge both of the population dynamics of a pest and of the economic threshold associated with it, is needed to determine if, when, and how many additional natural enemies are required to prevent economic losses (Ridgway 1970; Huffaker *et al.* 1977; Shumakov 1977).

Progress in the development of practical uses of manipulations of chrysopids undoubtedly has been limited by our lack of knowledge of the population dynamics of the pests and natural enemies in the agroecosystems in which manipulations are being attempted. Nevertheless, the knowledge that is available on the feeding and searching behavior of chrysopids has been very useful in designing manipulations.

Larvae of chrysopids are known to feed on a wide variety of small, soft-bodied insects, spiders and mites, as well as on eggs and small larvae of a number of lepidopteran insects (see Chapter 4.2.). Chrysopids are also effective searchers. For instance, Fleschner (1950) compared the feeding and searching behavior of *Stethorus picipes*, *Conwentzia* sp. and *Chrysoperla carnea* (= *californica)* by using the citrus red mite, *Panonychus (=Paratetranychus) citri* as prey. In these studies, *Chrysoperla carnea* larvae searched more area and consumed more prey than the other species. Also, Sundby (1966) compared *Coccinella septempunctata*, *Syrphus ribesii* and *Chrysoperla carnea* as predators of the green peach aphid, *Myzus persicae*, and reported that *Chrysoperla carnea* 'seems to rate highest in all qualifications for aphid-controlling ability.' Although chrysopids are obviously excellent aphid predators, their efficiency varies considerably depending upon the species of chrysopid and the species of aphid involved (Shuvakhina 1974). After comparative tests with a number of predators, Lingren *et al.* (1968) reported that larvae of *Chrysopa* spp. were among the most efficient predators of eggs and larvae of the bollworm, *Heliothis zea* and the tobacco budworm, *Heliothis virescens.* Boyd (1970, unpublished) reported that the kind of prey available was not particularly important for survival of chrysopid larvae but that a minimum quantity of prey was essential; the preference of *Chrysoperla carnea* for prey was found to be, in descending order, first instar *Heliothis* larvae; cotton aphids, *Aphis gossypii; Heliothis* eggs; and carmine spider mites, *Tetranychus cinnabarinus.* All instars of *Chrysoperla carnea* were capable of destroying *Heliothis* eggs and 1- to 3-day old *Heliothis* larvae. However, the predatory efficiency of chrysopids may be affected substantially by the structure of the plant on which they are searching. For instance, *Chrysoperla carnea* appears to be a particularly effective predator of *Heliothis* on cotton because the chrysopid larvae seek shelter from high temperatures and light intensity inside the bracts of squares, where larvae *of Heliothis* feed; thus the pest larvae becomes a primary target for the predators (Boyd 1970, unpublished).

Chrysopid adults may feed on honeydew, nectar, pollen, or they may be predaceous. Of about 30 species of chrysopids in which the feeding habits of the adult is known, females of some 15 species must consume aphids before producing eggs (Hagen & Bishop 1979); species that do not require aphid prey are more amenable to mass rearing and manipulation with food supplements and attractants than are those which do because of the availability of substitutes for the natural adult foods (Hagen & Tassan 1970).

### 8.2.3. *Field releases*

The very limited number of studies that have been reviewed here on feeding and searching behavior of chrysopid larvae still provide significant evidence as to why successful field releases of chrysopids have involved such target pests as aphids, spider mites, *Heliothis* spp. (particularly on cotton), and other small, soft-bodied insects. Examples of studies of chrysopids on various crops with various target pests have been summarized (Table 22).

Releases of chrysopids to control aphids on vegetable crops have received major attention in the USSR (Adashkevich & Kuzina 1974; Shuvakhina 1974; Beglyarov & Smetnik 1977; Radzivilovskaya & Daminova 1980). The release of second instar chrysopid larvae on peppers to control the green peach aphid, and the cowpea aphid, *Aphis craccivora,* was highly successful. Aphid numbers were reduced 94 to 98% six days after colonization, and yields of peppers were increased by 13%. Favorable results were also obtained with releases of second instar larvae at a predator-to-prey ratio of 1:5 on tomatoes and eggplant to control the green peach aphid. Aphid numbers were reduced by 72% on tomatoes and 43 to 44% on eggplant. Results were somewhat less favorable when chrysopids were released on peas to control the pea aphid, *Acyrthosiphon pisum;* a predator-to-prey ratio of 1.5:1 was required to obtain a high level of effectiveness. Likewise, release of chrysopids on fall cabbage at a predator-to-prey ratio of 1:1 was required to obtain 74% decrease in aphid numbers.

Other studies in the USSR have concentrated on releases of chrysopids on eggplant and potatoes to control the Colorado potato beetle, *Leptinotarsa decemlineata.* In early studies, distribution of chrysopid eggs on eggplant at a predator-to-prey ratio of 1:1 reduced the numbers of prey by 74%, and release of first instar chrysopid larvae at ratios from 1:1 to 1:5 destroyed 86 to 91%

*Table 22.* Some examples of manipulations of chrysopids by field releases

| Crop | Target pest | Reference |
|---|---|---|
| Cabbage<br>Pepper<br>Tomato<br>Eggplant<br>Peas | Aphids | Adashkevich & Kuzina 1974<br>Beglyarov & Smetnik 1977<br>Radzivilovskaya &<br>Daminova 1980 |
| Eggplant | Colorado potato beetle | Adashkevich & Kuzina 1971<br>Shuvakhina 1974 |
| Potato | Colorado potato beetle | Adashkevich & Kuzina 1971<br>Shuvakhina 1974, 1977, 1978 |
| Potato | Aphids | Shands *et al.* 1972 |
| Apple | European red mite | Miszczak & Niemczyk 1978 |
| Apple | European red mite | Yan 1981 |
| Pear | Grape mealybug | Doutt & Hagen 1949, 1950 |
| Mulberry<br>Catalpa | Comstock mealybug | Beglyarov & Smetnik 1977 |
| Cotton | Bollworm and<br>tobacco budworm | Ridgway & Jones 1969<br>Kinzer 1976, unpubl.<br>Ridgway *et al.* 1977 |
| Cotton | *Heliothis* spp. | Anonymous 1982 |
| Cotton | Aphids | Anonymous 1982 |

of the eggs of the Colorado potato beetle (Adashkevich & Kuzina 1971; Beglyarov & Smetnik 1977). Related studies reported by Shuvakhina (1974) indicated that distribution of chrysopid eggs even at a 1:1 ratio did not produce a satisfactory level of control. However, releases of chrysopid larvae at a predator-to-prey ratio of 1:20 provided quite promising results: beetle larvae were reduced by 95% on eggplant and 85% on potatoes. The superior results on eggplant were attributed to a slower rate of development of the beetle larvae on this plant than on potato. In later studies, distribution of chrysopid eggs in the above ratio was ineffective, whereas releases of chrysopid larvae to provide a predator-to-prey ratio of 1:10 were highly effective; a ratio of 1:26 provided some control, but yield losses did occur (Shuvakhina 1977, 1978).

Releases of chrysopid species (probably *Chrysoperla carnea)* onto potatoes in the USA reduced populations of the buckthorn aphid, *Aphis nasturtii,* by up to 96% throughout the season when ca. 84 000 larvae per hectare were released; additionally, populations of the green peach aphid were reduced by 83%, but the key pest, the potato aphid, *Macrosiphum euphorbiae,* was apparently unaffected (Shands *et al.* 1972).

Some promising results have been obtained in Poland and in the People's Republic of China with releases of chrysopids to control the European red mite, *Panonychus ulmi,* on apples (Miszczak & Niemczyk 1978; Yan 1981). In the studies conducted in Poland, release of one first instar chrysopid larva per 10 to 25 leaves was sufficient to greatly reduce the mite population and maintain it at a very low level.

Apparently, the very first definitive study of releases of chrysopids to control a pest involved the release of eggs of *Chrysoperla carnea* in the crowns of pear trees to control the grape mealybug, *Pseudococcus maritimus;* a substantial reduction in fruit infestation was obtained through three properly timed releases of 250 eggs per tree (Doutt & Hagen 1949, 1950). Chrysopids may have been concurrently under study to control the Comstock mealybug, *Pseudococcus comstocki,* on catalpa and mulberry (Beglyarov & Smetnik, 1977).

Releases of larvae of *Chrysoperla carnea* in field plots of cotton in the USA have been highly successful in reducing numbers of the bollworm and tobacco budworm (Ridgway & Jones 1969; Kinzer 1976, unpublished; Ridgway *et al.* 1977). Releases of eggs were successful in cages (Ridgway & Jones 1968) but were less successful in the field (Jones & Ridgway 1976). Significant reductions in populations of bollworm and budworm larvae were obtained with releases of 25 000 chrysopid larvae per hectare, and high levels of reduction were obtained by releasing 250 000 chrysopid larvae per hectare (Kinzer 1976, unpublished). In these studies, a complete mass production, larval rearing and field distribution system was developed (Reeves 1975, unpublished; Morrison & King 1977, Abies *et al.* 1979). However, costs of rearing adequate numbers of chrysopid larvae for use on cotton must be substantially reduced for this means of production and use to become practical. Use of chrysopids on cotton to control bollworm or possibly aphids under different conditions than above may be more feasible, and research is underway in the USSR and in the People's Republic of China to explore that possibility (Ishankulieva 1979;Radzivilovskaya 1980; Anonymous 1982).

### 8.2.4. *Environmental manipulation*

Field releases of artificially-reared insects involves direct manipulation of the insect itself. Populations of natural enemies can also be increased by providing a more favorable environment for the insect. The use of food supplements and the interplanting of crops have been of particular interest for increasing populations of chrysopids.

Initial attempts to increase predator populations, including chrysopids, involved bait sprays containing primarily sucrose (Schiefelbein & Chiang 1966; Carlson & Chiang 1973). Field applications of bait sprays to corn were designed to control the European corn borer, *Ostrinia nubilalis.* However, the most effective food supplements were developed during efforts to perfect a substitute for the natural honeydew used in rearing chrysopids in the insectary (Hagen 1950; Hagen & Tassan 1970). The initial substitute was based on a protein hydrolysate of brewers yeast and later on a yeast-fermented milk whey.

A limited number of studies with protein-based food sprays have been conducted with horticultural crops including pepper, potato, grape and apple (Table 23), but perhaps the most significant research has been conducted on the field crops cotton and alfalfa (Hagen *et al.* 1970a; Hagen & Bishop 1979). The initial studies with food sprays on alfalfa involved a mixture of protein hydrolysate of brewers yeast, sucrose, choline chloride and water. Weekly applications to alfalfa resulted in a three-fold increase in the number of chrysopid eggs present and resulted in reductions of populations of the spotted alfalfa aphid, *Therioaphis maculata* and the pea aphid. Related studies to examine the attractant properties of the food spray indicated that

*Table 23.* Some examples of manipulations of chrysopids by the use of food supplements and attractants

| Crop | Target pests | Reference |
|---|---|---|
| Pepper | Green peach aphid | Hagen& Hale 1974 |
| Potato | Green peach aphid | Ben Saad & Bishop 1976 |
| Grapes | A leafhopper, *Erythroneura comes* | White & Jubb 1980 |
| Apple | Green fruitworms, primarily *Orthosia hibisci* | Hagley & Simpson 1981 |
| Corn | European corn borer | Schiefelbein & Chiang 1966<br>Carlson & Chiang 1973 |
| Cotton | Bollworm | Hagen *et al.* 1971<br>Hagen & Bishop 1979 |
| Alfalfa | Aphids | Hagen *et al.*1971<br>Hagen & Bishop 1979 |

more than three times as many adults were attracted to caged, sprayed alfalfa than to caged, unsprayed alfalfa. Subsequent studies on alfalfa with food sprays containing fermented whey were also successful in increasing numbers of chrysopid adults and eggs and in reducing numbers of aphids (Hagen *et al.* 1970a). Related studies on cotton indicated that food sprays increased numbers of chrysopids and decreased numbers of bollworms and damaged bolls (Hagen & Bishop 1979). However, about 4.5 kg of the fermented whey product plus 4.5 kg of sugar applied in 25 to 40 1 water applied every one or two weeks was needed to attract and induce oviposition from *Chrysoperla carnea* (Hagen & Hale 1974). Later, Hagen *et al.* (1976) studied tryptophan in artificial honeydews as an attractant for adult *Chrysoperla carnea.*

Although food sprays that also contain attractants have been used successfully to increase numbers of chrysopids and reduce pest populations, the successful use of food sprays is limited to those situations in which the natural population of chrysopids is adequate to produce the eggs needed to provide satisfactory levels of control.

Interplanting (intercropping) with selected plant species provides another means of increasing populations of natural enemies (Rabb *et al.* 1976). Natural enemy populations were enhanced in cotton by adjacent plantings of grain sorghum (Burleigh *et al.* 1973), and movement of chrysopids into cotton from adjacent plantings of sorghum have also been observed (Fye & Carranza 1972). Interplantings of forage sorghums with cabbage, a technique specifically designed to increase populations of chrysopids, resulted in a tenfold increase in the number of chrysopid eggs on cabbage; the numbers of chrysopid eggs were further increased with the addition of food sprays (Wellik & Slosser, Texas Agricultural Experiment Station, Vernon, TX, USA, unpublished data).

Environmental manipulations have been successful in increasing chrysopid populations. However, economic methods of consistently obtaining adequate levels of pest control by this approach have yet to be developed.

8.2.5. *Efficacy*

The potential for utilizing chrysopids for biological control in the field has been clearly demonstrated with different types of manipulation. However, additional attention should be given to predicting and improving the efficacy of chrysopids. Efficacy is governed by three major factors: (i) density of the predator and prey, (ii) distribution of prey and area to be searched, and (iii) prey preferences of chrysopids and available alternative prey species. Also, the level of efficacy desired from chrysopids may be greatly influenced by the effect of other mortality factors on the pest population. The use of predator-to-prey ratios has proved to be a useful means of predicting efficacy of chrysopids in the field on vegetable crops and potatoes (Shuvakhina 1974, 1977, 1978; Beglyarov & Smetnik 1977). In other situations, the size of the area to be searched and the structure of the substrate plant may be more important in predicting efficacy (Boyd 1970, unpublished; Miszczak & Niemczyk 1980). Availability of alternate prey may also be critical in some instances, particularly when aphids are abundant and the target pest is a lepidopteran pest (Ridgway & Jones 1968; Anonymous 1982).

In those instances in which naturally occurring populations of predators and parasites have a major impact on the pest population, an assessment of the efficacy of the naturally occurring predators is essential in predicting the minimum number of additional chrysopids needed to prevent economic loss. In this regard the use of computer-based population models can be very useful. Specifically, a model designed to predict populations of the bollworm and tobacco budworm has been developed; this model has been highly successful in predicting oviposition by these pests (Hartstack *et al.* 1976). A component of that model is designed to estimate the efficacy of the predators. Efficacy indexes have been developed for eight groups of key predators of pest eggs and larvae; chrysopids comprise one of these key predator groups (Abies *et al.* 1983). The model can also be used to estimate the effects of releasing additional natural enemies, such as chrysopids.

Thus, the economic feasibility of manipulating of chrysopids can be enhanced through the use of refined procedures for estimating and predicting their efficacy, and approaches to increasing efficacy can also be identified.

### 8.2.6. *Status and prospects*

Substantial progress has been made during the past two decades towards the development of practical applications of biological control through manipulation of chrysopids under field conditions. The use of food supplements, attractants and interplanting of crops provides some very intriguing possibilities, but these methods have not consistently resulted in increases in numbers to the extent achieved with releases of mass-reared insects. Perhaps a combination of releases and other manipulations might prove to be most efficient. Although releases of chrysopids have produced desirable levels of pest control on a number of crops grown in the field, the current costs of rearing the large numbers needed to produce the desired effects would seem to preclude large-scale practical use at the present time. Still, interest in the use of chrysopids for biological control remains high. In the USA, chrysopids and food supplements may be purchased commercially from various companies (Brunetti 1981, unpublished) and substantial research efforts are continuing in Western Europe, the USSR, the People's Republic of China, and other parts of the world. Also, the experimentation on manipulations of chrysopids has provided important new knowledge on the regulation of pest populations by predators; this knowledge will be useful in developing improved pest management systems regardless of the future practical use of manipulations of chrysopids.

Additional research on the biology, behavior, nutrition, mass rearing, population dynamics, and management systems will undoubtedly result in the more effective use of chrysopids and other natural enemies for the biological control of pests.