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## THE INTEGRATION OF CHEMICAL AND BIOLOGICAL CONTROL OF THE SPOTTED ALFALFA APHID

### The Integrated Control Concept

**Vernon M. Stern, Ray F. Smith, Robert van den Bosch, and Kenneth S. Hagen**

### Field Experiments on the Effects of Insecticides

**Vernon M. Stern and Robert van den Bosch**

### Impact of Commercial Insecticide Treatments

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Chemical and biological control are regarded as two main methods of suppressing insects and spider mites. These two methods are often thought of as alternatives in pest control. This is not necessarily so, for with adequate knowledge they can be made to augment one another.

Biological control is part of the permanent natural control of population density. Chemical controls involve only immediate and temporary decimation of localized populations and do not contribute to natural control. Natural control may keep a pest species from ever reaching the economic-injury level or it may permit economic outbreaks. The frequency of these pest outbreaks varies from a regular to an occasional occurrence depending upon the level of the general equilibrium position in relation to the economic injury level and the types of fluctuations about the general equilibrium position.

Integrated control combines and integrates biological and chemical controls. Chemical control is used as necessary and in a manner which is least disruptive to biological control. Integrated control may make use of naturally occurring biological control as well as modified or introduced biological control. Thought must be given to the biological control of not only the primary pest under consideration but also other potential pests.

Integrated control is most successful when sound economic thresholds have been established, rapid sampling methods have been devised, and selective insecticides are available. In some situations, the development of integrated control requires the augmentation of biological control through the introduction of additional natural enemies or modification of the environment.

Integrated control of the spotted alfalfa aphid has been achieved in California. Economic thresholds were established so that insecticides are applied only when damage is imminent. Native predators, introduced parasites, and entomogenous fungi now keep the spotted-alfalfa-aphid populations below the economic threshold for most of the year. When population counts in the individual field clearly demonstrate that a field is threatened, Systox is applied at low dosages. These chemical treatments give adequate control, but do not necessarily eradicate the aphids. Most of the predators and parasites survive and persist on the remaining aphids.

# IMPACT OF COMMERCIAL INSECTICIDE TREATMENTS[1]

**RAY F. SMITH and KENNETH S. HAGEN**

ECOLOGICAL STUDIES of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), in northern California during 1955, 1956, and 1957 have revealed that native predators play significant roles in governing the density of this aphid (Dickson, Laird, and Pesho, 1955; Stern, van den Bosch, and Born, 1958; van den Bosch *et al.*, 1959*b*; Smith and Hagen, 1956; Hagen and Smith, 1958). Throughout California these predators, along with entomophorous fungi, imported parasites, and physical factors of the environment, retain the spotted-alfalfa-aphid populations below the economic threshold during most of the alfalfa-growing season. At certain times of the year, the physical factors are the most important; at other times or within the same period at different localities any one of the biotic agents may be the most significant controlling factor; on other occasions, any or all combinations may be involved. Sometimes, or in certain alfalfa fields, the environmental conditions may be such that none of the regulating factors operate efficiently, and the aphid population rapidly increases to economic levels.

This study of the effect of insecticidal treatments on the native predators was started in the early spring, 1956, and was restricted to the central and northern parts of California. In 1956 and 1957 the introduced aphid parasites *Praon palitans* Muesebeck and *Trioxys utilis* Muesebeck had not yet become established over the entire area covered by this study (van den Bosch, 1956, 1957; van den Bosch *et al.*, 1959*a*). Thus even though the population fluctuations of the aphid and its natural predators were followed throughout the two years (1956–1957) in 40 commercial alfalfa-hay fields, in only 3 of these fields did the introduced hymenopterous parasites reach significant abundance during the study period. This paper is therefore essentially a report of the effects of insecticidal treatments on natural predators in a selected group of the 40 fields. A more detailed analysis of natural control in each of the 40 fields is in preparation.

## INSECTICIDE APPLICATIONS AND POPULATION COUNTS

The study areas, which were scattered over the central portion of California, were established to obtain ecological data under the variety of climatic conditions which prevail there. Each study area was approximately 3 acres and located in a commercial alfalfa-hay field operated under normal cultural practices. All decisions concerning irrigation, fertilization, harvesting, and insect-control procedures were made by the farmer without special reference to any requirements of the investigation. Thus these study areas were not controlled experimental plots.

The aphid population trends were followed by the canister-count method first developed by Gray and Schuh (1941) for pea aphid, *Macrosiphum pisi* (Kaltenbach), on peas. In each study area on each sampling day, 4 to 8

[1] Received for publication August 13, 1958.

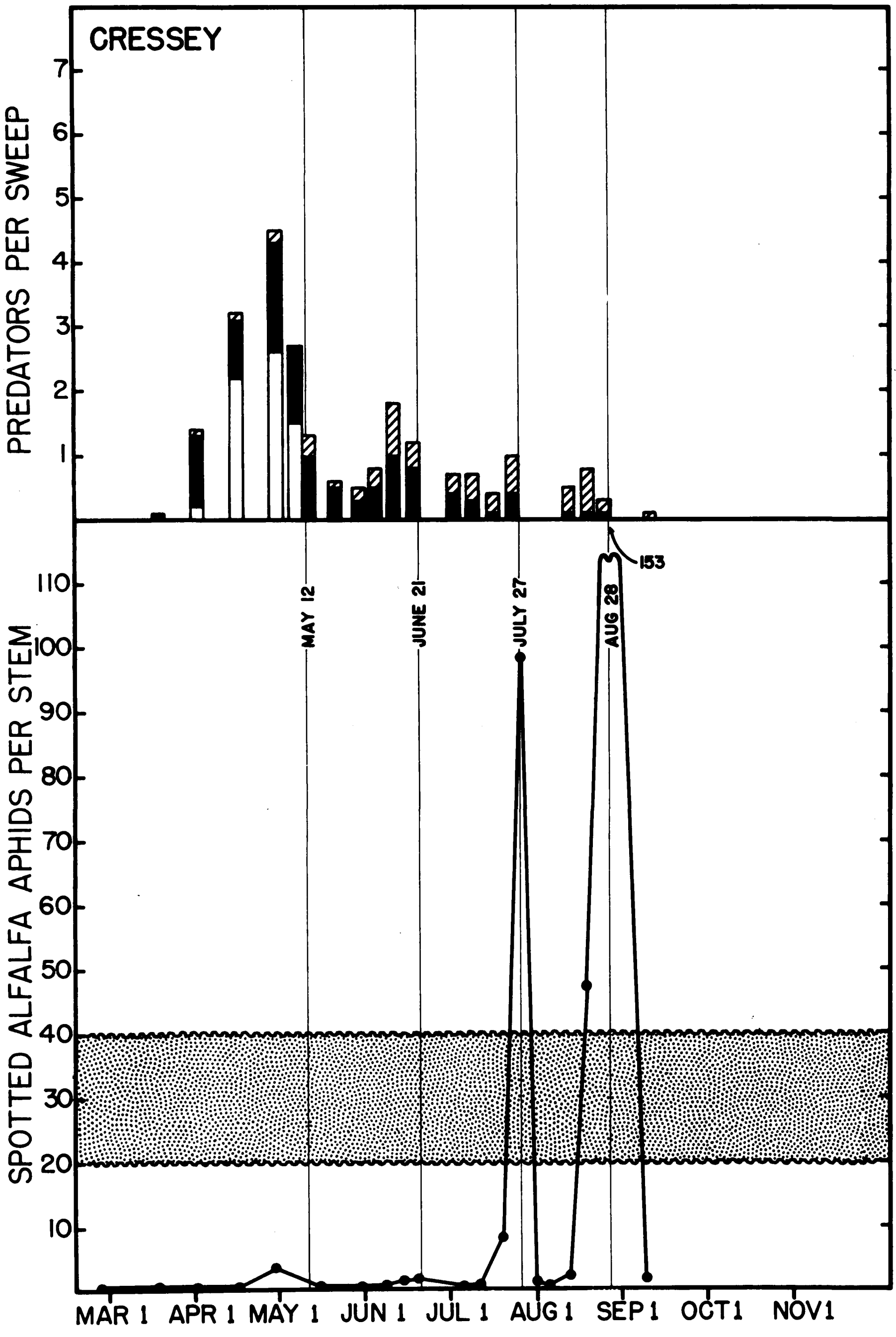


Fig. 1. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Cressey, Merced County, 1956. The dated vertical guide lines indicate cutting times. Stippled area represents the economic threshold for spotted alfalfa aphid. Predators include coccinellid adults (solid bar), coccinellid larvae (open bar), and other potential aphid predators (cross-hatched bar).

samples of 25 stems each were collected. The aphids were shaken from the stems in the canisters and brought into the laboratory for counting. Although all species of aphids were counted, only the data for *Therioaphis maculata* are presented here.

The predator populations were followed by the sweep-net method. In each study area on each sampling day ten ten-sweep samples were taken. All predators were identified and tallied in the field as they came from the net.

The chemicals used and the time of application were decisions of the grower and were, with one exception, applied in a normal commercial manner either by the farmer or by commercial operators. The exception was the Selma field: here, in addition to the grower's commercial practice, a special schedule of treatments was carried out by the local farm advisor.

## APHID AND PREDATOR POPULATIONS

For the graphs in this paper, predators are grouped into three categories, the first two of which are coccinellid adults and larvae respectively. *Hippodamia convergens* Guérin and *H. quinquesignata punctulata* LeConte were the dominant species. *H. sinuata sinuata* Mulsant, *H. parenthesis* (Say), *Coccinella novemnotata franciscana* Casey, and, occasionally, other species, were important in some areas. The third predator category comprises a complex of species including larvae of *Chrysopa plorabunda* Fitch, adults and nymphs of *Nabis ferus* (Linnaeus), *Geocoris pallens* Stål, *G. punctipes* (Say), *G. atricolor* Montandon, and larvae of aphidophagous syrphids. Other predators and insects were recorded but are not reported here.

In interpreting the aphid population trends, it must be remembered that occasionally the time intervals between samples were not short enough to reflect completely the rapid population changes. In general, insecticidal treatments or the harvesting of the alfalfa hay immediately reduced the aphid populations to low levels. Where such effects would create confusion in the interpretation of the graphs, the connecting lines are omitted and the inferred direction of the population change is indicated by an arrow.

### With No Insecticidal Treatments

**Cressey.** The usual pattern of relation between the spotted alfalfa aphid and its coccinellid predators in the San Joaquin Valley is shown by the situation in a field near Cressey, Merced County, in 1956 (fig. 1). During the first cutting period, a brood of coccinellid larvae developed on a moderate population of pea aphids (not shown on the graph). These beetles, in combination with *Entomophthora* fungus disease, reduced the aphid populations to low levels at the end of the first cutting period (May 12). During the second cutting period the aphid populations were held at low levels by the newly emerging and immigrating adult Coccinellidae. At this time there were not sufficient aphids present for the coccinellids to reproduce significantly. In the absence of significant numbers of aphidophagous predators or other population depressants, the spotted-alfalfa-aphid populations rose rapidly during the latter half of the third cutting period. The maximum recorded population count during this period was 98 aphids per

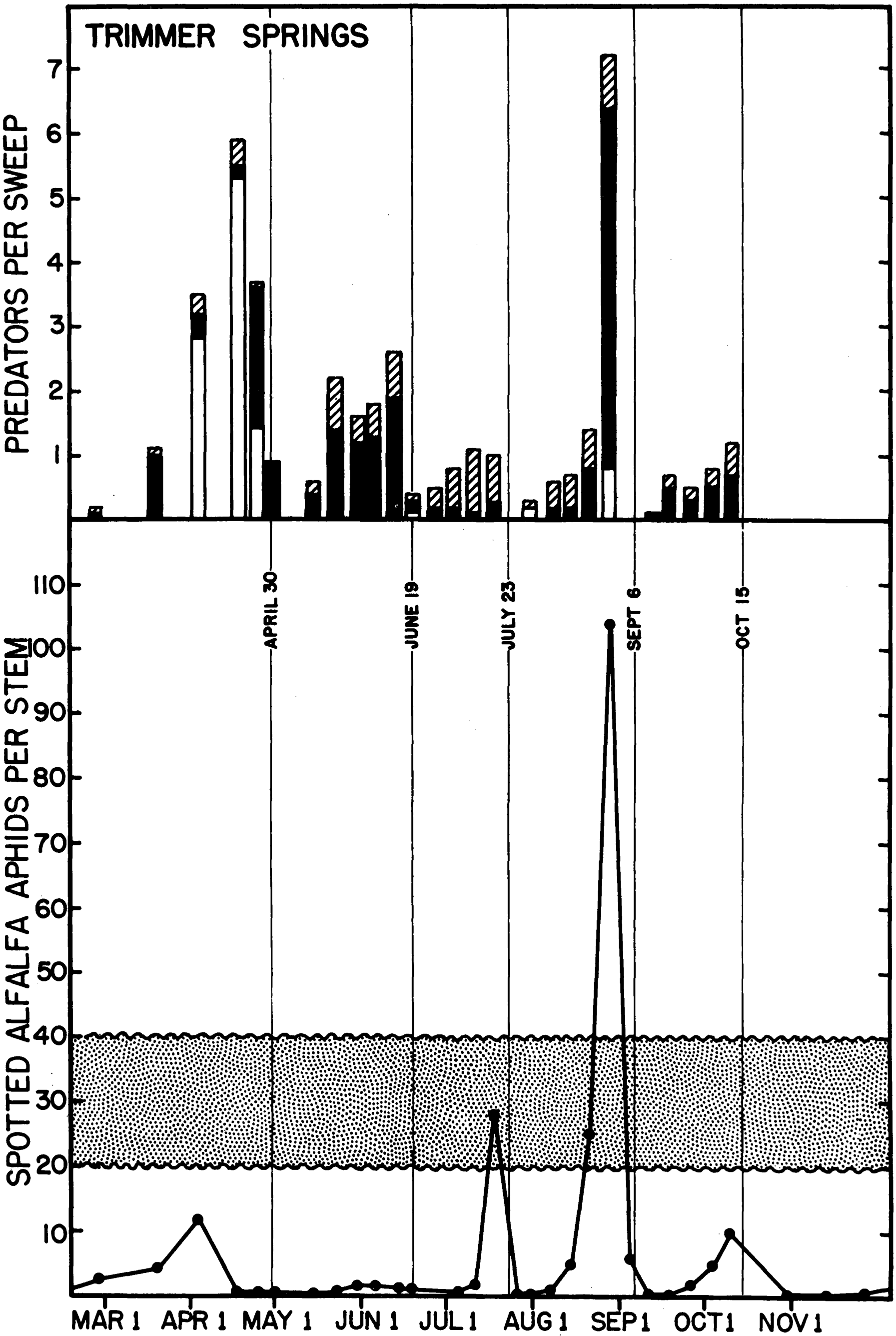


Fig. 2. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Centerville, Fresno County, 1956. Symbols as in fig. 1.

stem immediately before harvest (July 27). When the field was cut the aphid population dropped to a very low level.

Recovering from the effects of cutting, the spotted-alfalfa-aphid population in the Cressey study area again rose rapidly, in the absence of significant number of predators, to a level of 153 aphids per stem immediately before harvest of the fourth cutting. Again, after this cutting, the populations dropped to a low level.

**Centerville.** A very similar situation prevailed in the study area on Trimmer Springs Road near Centerville, Fresno County, in 1956 (fig. 2). During the latter half of March a flight of coccinellid adults entered this study area when the combined pea aphid and spotted-alfalfa-aphid populations were approximately 15 per stem. All coccinellid species reproduced and contributed significantly to the reduction in aphid abundance. During the second cutting period, the adult coccinellid population averaged over 1 per sweep and on June 6 the maximum combined aphid population was 1.5 aphids per stem. *Hippodamia convergens* and *H. quinquesignata punctulata* are not able to reproduce on this low population of aphids. On the other hand, *H. parenthesis* and *H. sinuata sinuata,* which together made up about one fourth of the coccinellids in this field, did reproduce to a limited extent. The larvae and adults of these two species, the few remaining adults of *H. quinquesignata punctulata* and large populations of *Nabis ferus* and *Geocoris,* which had developed on a high *Lygus* population, combined to hold the aphid populations at a low level until July 5. Following a reduction in their abundance after the harvest of the previous crop, the spotted-alfalfa-aphid population rapidly increased in the fourth cutting period on the new plant growth, when predators were nearly absent. A level of 104 aphids per stem was reached on August 29. The reduction in the aphid population in the latter part of this period was the result of a fungus epizoötic combined with predation by lady beetles and syrphid flies, which moved into the study area from other fields.

**Effects of Cutting.** In many instances the effect on the aphid population of cutting the alfalfa is comparable to a chemical treatment or heavy parasitism or predation. Immediately after the mowing, the cut hay dries, rapidly eliminating the abundant food source; only a scattered number of green leaves or new alfalfa shoots are available at the base of the plants for the aphids. Furthermore, soil surface temperatures in harvested alfalfa fields often exceed the upper limit for aphid survival. The aphids that are able to find leaves or shade at the base of the plants are concentrated in so small an area that predator efficiency is markedly increased. But it should be mentioned that aphid populations often reach damaging numbers many days prior to the normal cutting date. Therefore, only in special instances can a cutting be used as a means of economically controlling the populations.

## With a Fixed Insecticidal Schedule: Selma

During the 1956 growing season, a study was conducted near Selma to determine the effects of grower treatments and an indiscriminate fixed spray schedule on native predators and yields of alfalfa.

In this experiment four plots were treated according to a fixed schedule,

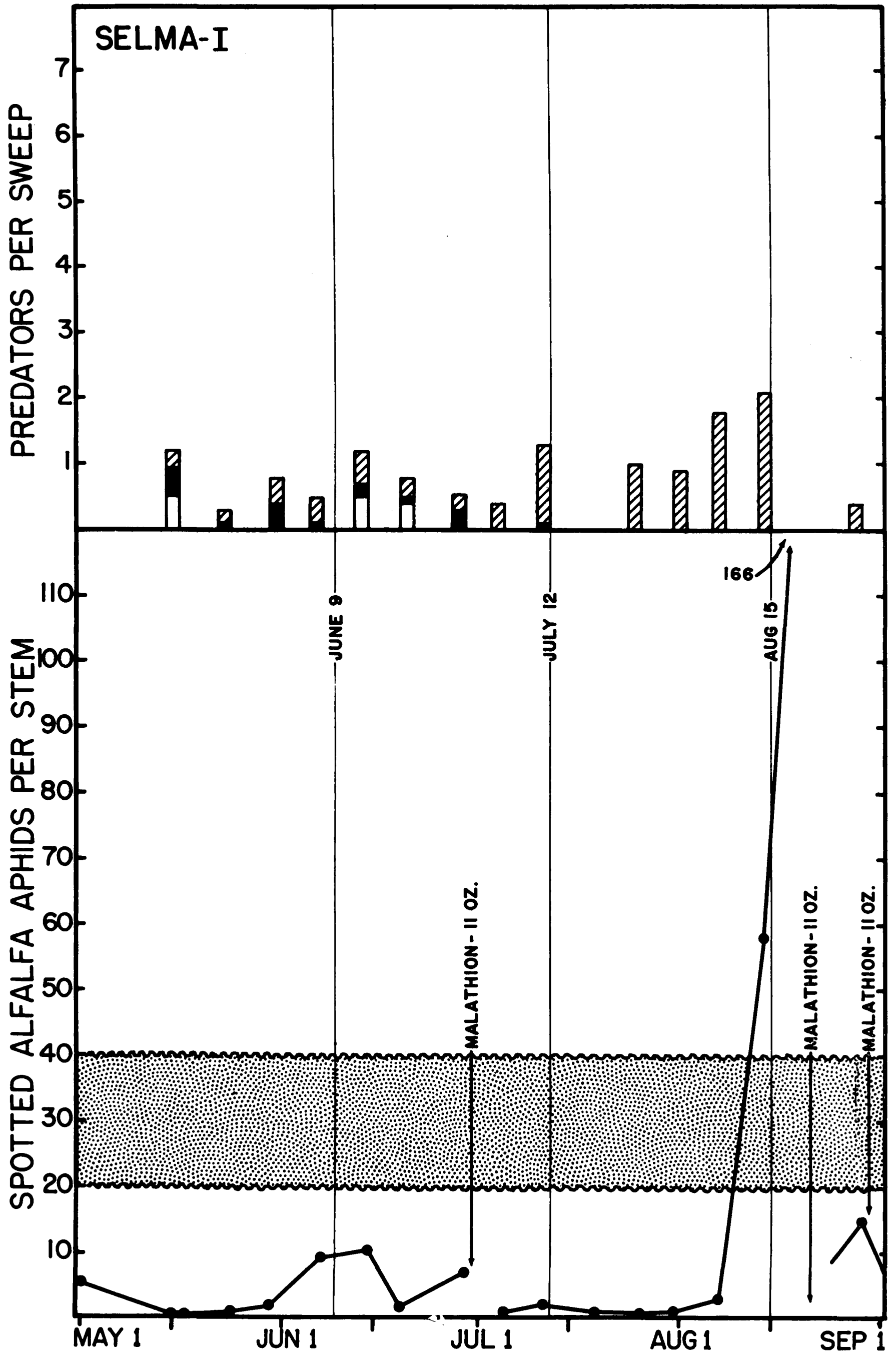


Fig. 3. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Selma, Fresno County, 1956. Insecticidal treatments applied by ground rig on basis of growers' evaluation of aphid hazard. Symbols as in fig. 1.

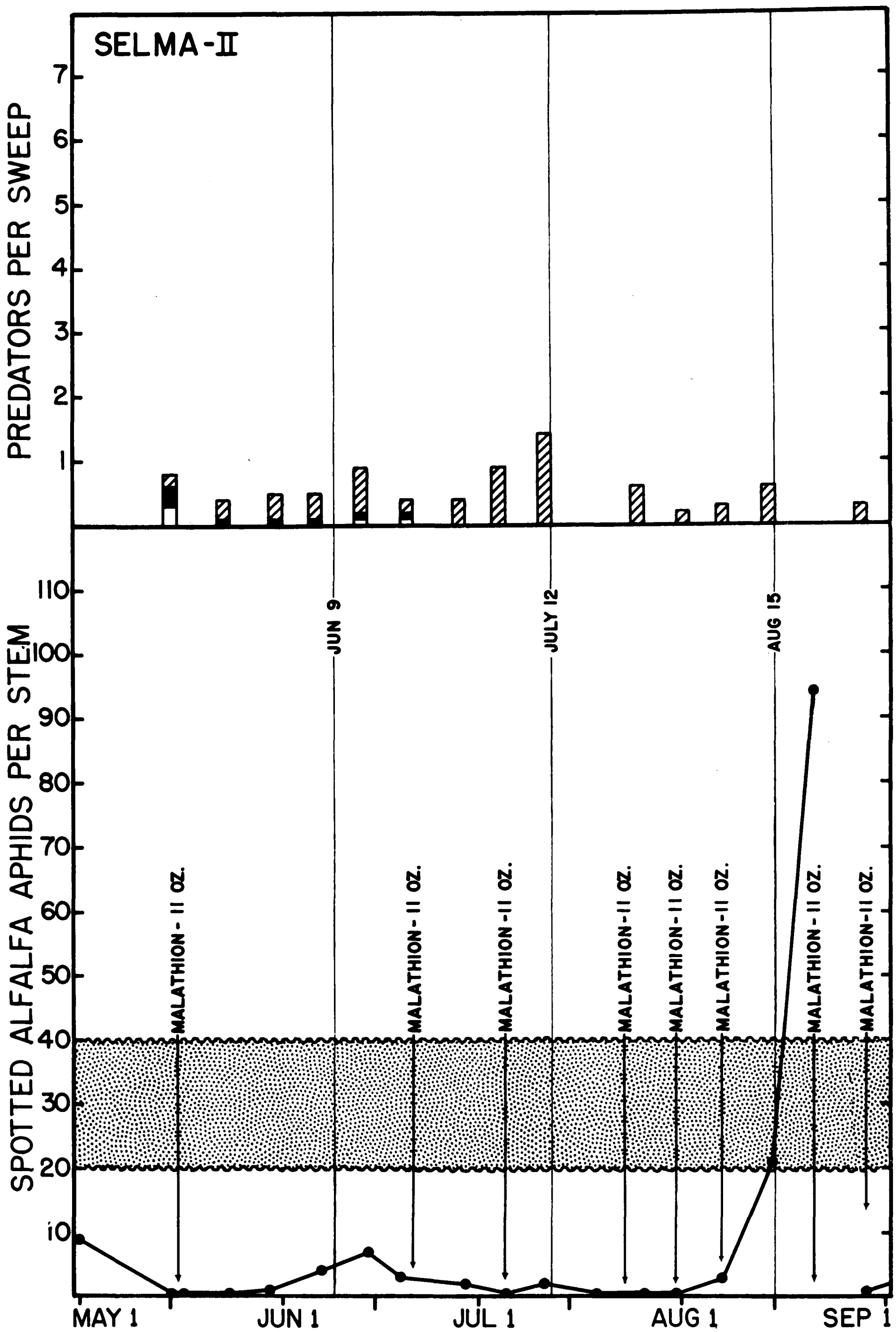


Fig. 4. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Selma, Fresno County, 1956. Insecticidal treatments applied by ground rig on basis of a fixed schedule. Symbols as in fig. 1.

TABLE 1

RELATIVE NUMBERS OF COCCINELLIDAE IN GROWER-TREATMENT AREAS AND FIXED-TREATMENT AREAS; SELMA, 1956

| Coccinellid species | Coccinellidae per hundred sweeps | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Areas treated on June 21* | | | | | | Areas not treated June 21† | | | | | |
| | June 13 | | June 20 | | June 28 | | June 13 | | June 20 | | June 28 | |
| | Adults | Larvae | Adults | Larvae | Adults | Larvae | Adults | Larvae | Adults | Larvae | Adults | Larvae |
| *Hippodamia convergens* | 5.0 | 0.6 | 5.6 | 2.5 | 0 | 0 | 4.6 | 12.7 | 0.4 | 11.3 | 20.8 | 0 |
| *Hippodamia quinquesignata* | 1.9 | 2.5 | 3.9 | 2.5 | 0 | 0 | 5.6 | 19.2 | 1.0 | 6.7 | 17.9 | 0 |
| *Hippodamia parenthesis* | 2.5 | 4.2 | 1.9 | 0.3 | 1.1 | 0 | 1.9 | 22.7 | 1.7 | 2.3 | 30.4 | 0.8 |
| All Coccinellidae | 9.7 | 7.6 | 11.7 | 5.3 | 1.1 | 0 | 12.5 | 57.5 | 3.3 | 20.5 | 69.5 | 0.8 |

* Three fixed-schedule plots.
† Four grower-treatment plots.

without regard to the existing insect populations; three other plots received the grower's normal treatment program, in which the first appearance of honeydew was the signal to treat. Each experimental plot was approximately 1.7 acres, and each treatment was applied by a ground sprayer at the rate of 11 ounces of actual malathion per acre.

Population trends, treatments, and the resultant effects of the sprays on aphid predators from a plot of each of the two types of schedule are shown in figures 3 and 4. The grower's program (see table 2) involved no treatments in the first two cutting periods, one (June 30) in the third period; two (July 31 and August 8, grower treatment A in table 2) in some parts of the field and none (grower treatment B, table 2) in other parts of the field in the fourth period; and three (August 21, 30, and September 19) in the fifth. The fixed schedule involved no treatment in the first cutting period, one in the second period (May 16), two in the third (June 21 and July 5), three in the fourth (July 23, July 31, and August 7), and three in the fifth (August 21, August 29, and September 12).

**Populations during Second and Third Cutting Period.** In the plots subjected to the fixed schedule, the lady-beetle population (approximately 0.4 adult and 0.3 larva per sweep) was eliminated by the first treatment on May 16 (fig. 4). In addition, this treatment appeared to affect the lady-beetle populations in plots not treated at this time (fig. 3), as there was some movement of the coccinellids from plot to plot within the field. In the treated plots, the lady-beetle population started to increase again by immigration (fig. 4) in the early part of the third cutting period, and apparently had begun to reduce the aphid infestation when another treatment was applied on June 21. No lady beetles were taken in this plot for the remainder of the growing season. The impact of the malathion treatment of June 21 on coccinellids is shown in table 1. This table is based on the data from the seven plots in the study area rather than the single plots represented in figures 3 and 4. Prior to the June 21 treatment there was a much higher lady-beetle population in the grower-treatment plots than in the fixed-schedule plots. This is a reflection of the May 16 application in the latter plots, which reduced both aphids and coccinellids (fig. 4). The combined pea-aphid and spotted-alfalfa-aphid population in the untreated plots averaged 0.6 aphid per stem on May 24, 2.1 on May 30, and 10.0 on June 7. This relatively low aphid population provided sufficient food for coccinellid reproduction. By contrast, fixed-schedule plots, which received the May 16 application, had 0.3 aphid per stem on May 24, 0.9 on May 30, and 4.0 on June 7, and little coccinellid reproduction. The low numbers of lady-beetle larvae present in the untreated plots on June 28 resulted largely from pupation.

The first insecticide application by the grower on June 30 eliminated the moderate population of lady beetles which had up to that time kept the spotted-alfalfa-aphid population at a low level (fig. 3). In July and August the only predators remaining in this area in significant numbers were *Nabis* and *Geocoris,* which had developed mainly on a population of *Lygus.*

**Populations during Fourth Cutting Period.** During the fourth cutting period, the aphid populations remained at low levels until the second week of August, when large numbers of alate spotted alfalfa aphids flew into

TABLE 2

YIELD PER ACRE AND TOTAL APHID-DAYS ON THE SECOND TO FIFTH CUTTINGS; SELMA, 1956

| Treatment | Treatment dates | Yield, tons per acre, in cuttings II to V | | | | Total aphid-days in cutting periods II to V | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | II | III | IV | V | II | III | IV | V |
| Grower treatment A | June 30, July 31, Aug. 8, 21, 30, Sept. 19 | 2.18 | 1.84 | 1.46 | 1.18 | 132 | 154 | 348 | 935 |
| Grower treatment B | June 30, Aug. 21, 30, Sept. 19 | 2.31 | 1.93 | 1.71 | 1.20 | 102 | 200 | 197 | 562 |
| Fixed schedule | May 16, June 21, July 5, 23, 31, Aug. 7, 21, 29, Sept. 12 | 2.19 | 1.68 | 1.56 | 1.17 | 82 | 72 | 84 | 352 |

the study area. The outside margins were infested first and in some plots aphid-infestation levels were as high as 134 aphids per stem on August 7. The two marginal plots were treated on August 8, for there were no predators to check further population increase. The plot represented in figure 3 was in the interior of the study area and received no treatments during the fourth cutting period. Due to the differential flight into the field, in this untreated plot the aphid population level did not reach its peak (57.7 aphids per stem) until August 14. In the plots receiving three treatments (fig. 4) in the fourth cutting period, the aphid population averaged 21.3 per stem on August 14.

**Populations during Fifth Cutting Period.** After the cutting of the fourth crop on August 15, the study area could not be treated again until the bales of alfalfa had been removed. During this period the aphid populations increased rapidly in the absence of predators. In the plots which were not treated in the fourth cutting period, the spotted-alfalfa-aphid infestation level rose as high as 166 aphids per stem. In these plots, the growth of the fifth crop was markedly delayed.

By the end of the fifth cutting period, heavy spider-mite infestations had developed in all plots receiving the fixed-schedule treatment. In some parts of these plots the mite infestations caused serious defoliation or heavy leaf damage on the lower halves of the plants. In other parts of the study area, mites, though present, did not occur in damaging numbers.

**Insect Injury.** The small difference in aphid populations as a result of the two types of treatments during the second and third cutting periods did not affect yields. This emphasizes the futility of "insurance" treatments not based on insect populations or of treatments applied according to a fixed schedule not based on aphid abundance. In the second cutting period, the cumulated aphid-days (one aphid-day equals one aphid per stem per day) were 117 in the plots with no treatment and 82 in the plots receiving the May 16 treatment. The yield was 2.24 tons per acre in the former and 2.19 in the latter. In the third period the cumulated aphid-days were 177 in the plots with no treatment and 72 in the plots receiving the June 21 and July 5 treatments. The yield was 1.88 tons per acre in the untreated plots and 1.68 tons per acre in the plots receiving two treatments of malathion in the third cutting period.

At the time of harvest, alfalfa in the plots treated once during the fourth cutting period on August 8 (grower treatment A, table 2) was slightly sticky with honeydew and there was slight sooty mold on the bottom 10 inches of growth. Alfalfa in the plots receiving no treatment during the fourth cutting (grower treatment B, table 2) had light honeydew on the lower leaves and some leaf injury from lepidopterous larvae [*Prodenia praefica* Grote and *Loxostege sticticalis* (Linnaeus)]. The fixed-schedule plots showed no spotted alfalfa-aphid honeydew or caterpillar injury, but light spider-mite damage was appearing in some plots. These pest levels were not correlated with yields (table 2) or protein content of the cured hay.

In summary, the aphid-population differences between plots receiving excessive treatments and those receiving the grower's treatment schedule were not of economic significance.

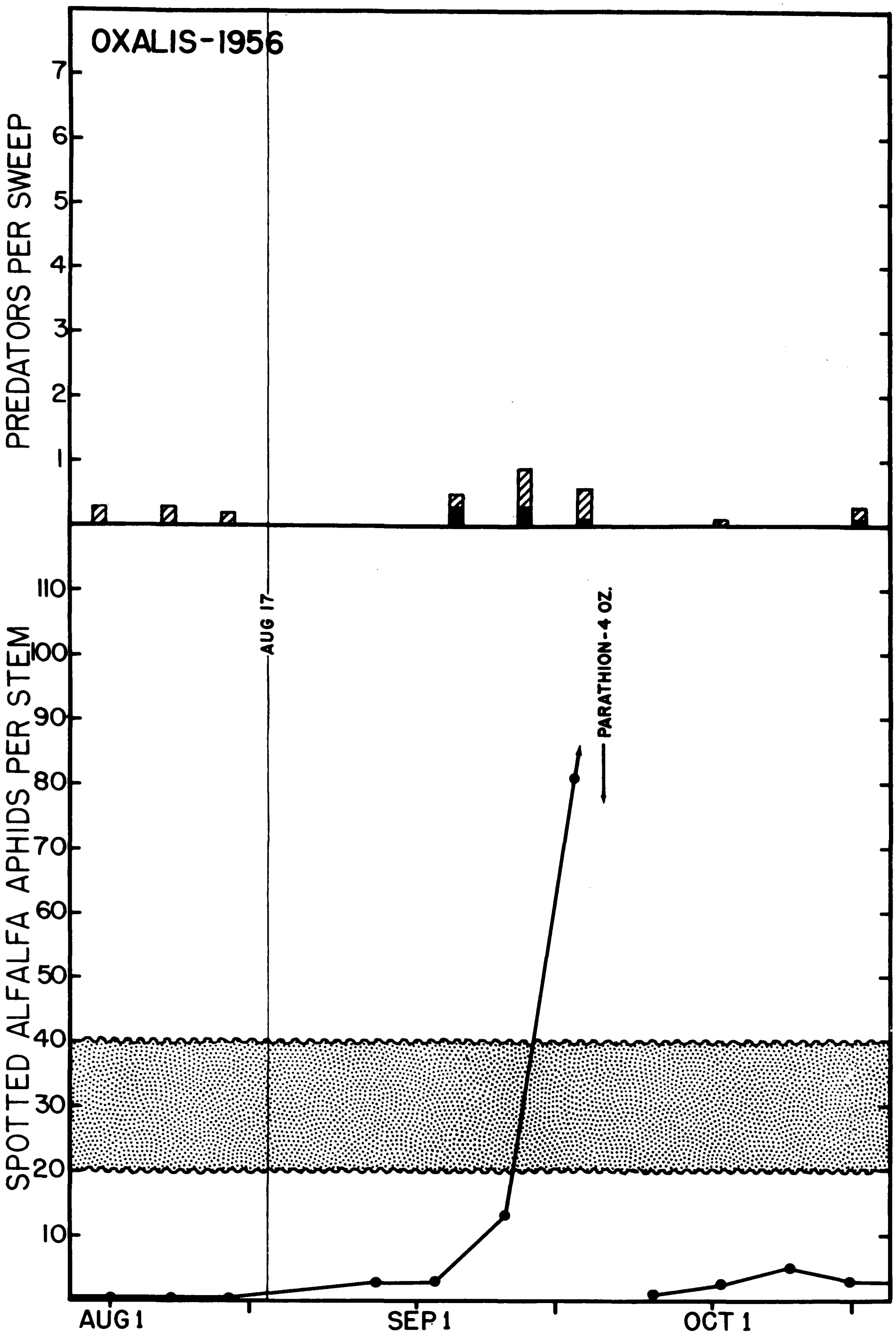


Fig. 5. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Oxalis, Fresno County, 1956. Symbols as in fig. 1.

## With Nonselective Insecticides

**Selma.** As has been demonstrated in a companion paper (Stern and van den Bosch, 1959) when nonselective insecticides, such as malathion or parathion, are used to lower threatening aphid populations, most of the enemies of the aphids are also eliminated. The work of Stern and van den Bosch is supported by the evidence in the Selma study area, where the use of malathion eliminated practically all lady beetles from the field (table 1, figs. 3 and 4). The surviving predators were almost entirely *Geocoris* and *Nabis*. These predaceous bugs had developed on a heavy lygus-bug population and when the alfalfa growth was short they were significant in helping to keep the aphid population low. When a large number of aphids flew into the field about the second week of August, however, they were not able to prevent the increase of the aphids to economic levels. In spite of three malathion treatments in the fourth cutting period, the aphid population increased rapidly in mid-August.

Treatment with a nonselective insecticide does not necessarily provoke an immediate resurgence of the aphid population. If the insecticidal treatment has been thorough and adequate and the aphid population is nonresistant, resurgence may not occur until the population has had an opportunity to complete two or three generations. More often resurgence occurs when there is a heavy immigration of winged aphids into the field from neighboring fields. These adults, in the absence of biotic checks, can quickly increase the aphid population to economic levels.

**Oxalis.** Under certain environmental conditions, resurgence may not occur because the plant growth in such alfalfa fields is unsatisfactory for the aphids. The situation illustrated in figure 5 is an example of such a field. During late July, 1956, the populations of *Therioaphis* in this field had been reduced to low levels by hot, dry conditions. Irrigation had been delayed and on 8 out of 15 days from July 11 to July 25 the maximum air temperature was 95°F or higher. The alfalfa was cut early on August 17 to reduce a threatening infestation of lepidopterous larvae (*Colias philodice eurytheme* Boisduval and *Prodenia praefica*). The first irrigation of the fifth cutting period was delayed until September 3. With the renewal of growth following irrigation, and the arrival of a moderate flight of aphids into the field the aphid population started to increase. A treatment for *Colias* and *Therioaphis* with 4 ounces of parathion per acre on September 20 eliminated the moderate population of predators which had started to develop. The aphid population did not rebound because of the lack of a significant flight into the field and the unfavorable plant conditions. In late September and early October the plants were woody and overmature, with most of the lower leaves gone. The length of this cutting period was 62 days.

The following year, in this same field, two malathion treatments were applied during July and August (fig. 6). During the third cutting period the spotted-alfalfa-aphid population rose to a level of 80 per stem on July 3. During the previous 2 weeks a population of approximately one coccinellid adult per sweep had been present. This population of beetles was not large enough to cope with a flight of approximately 0.8 alate per stem into

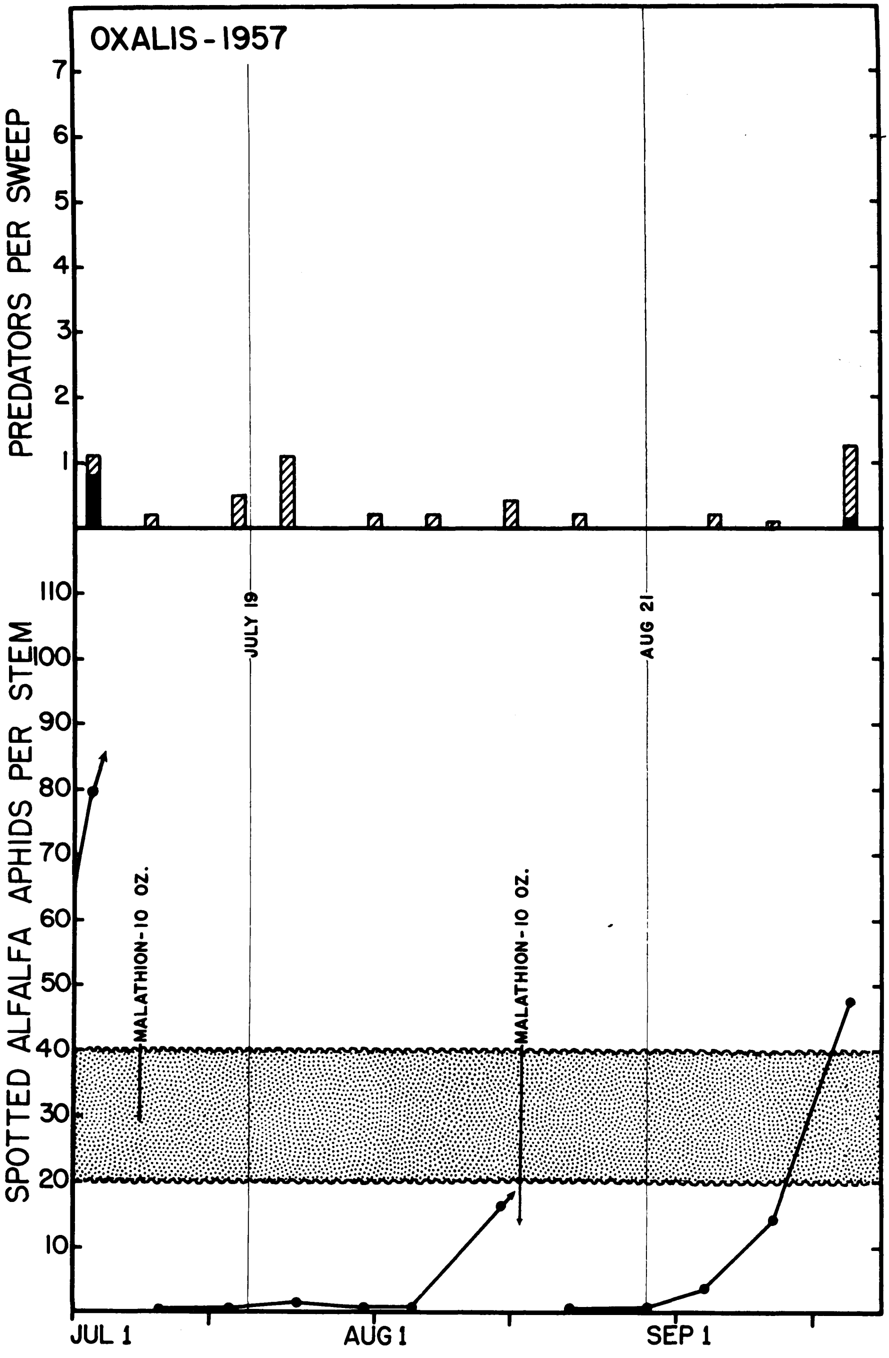


Fig. 6. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Oxalis, Fresno County, 1957, before and after treatments with a nonselective insecticide (malathion). Symbols as in fig. 1.

the field. The coccinellids were able to reproduce and on July 4, 97 per cent of the females were gravid. A treatment with malathion on July 8, eliminated all of these coccinellid adults and any larvae which hatched later.

In the following cutting period, the field was not irrigated until July 31. New growth followed this irrigation, after which a flight of alate aphids averaging about 1 per stem moved into the field and in the presence of very few predators rapidly produced an economic infestation; thus, another treatment was necessary in mid-August. In September the aphid population again rose rapidly.

Additional effects of nonselective treatments are shown in figure 12.

## With Selective Insecticides

**Patterson.** Up to August 5, 1957, the spotted-alfalfa-aphid population had remained low in the Patterson field (fig. 7). The maximum count had been 15.5 spotted alfalfa aphids per stem on July 3. These low infestation levels largely resulted from the activity of coccinellids. During the third cutting period, in late July and early August, the coccinellid populations dropped to very low levels, ranging from 0 to 3 adults per 100 sweeps. In early August a large flight of alate *Therioaphis* moved into the field and, with predators nearly absent, the aphid population increased to high levels. However, as the time of harvest was near, the crop was mowed. The high aphid population that developed late in the third cutting period and on the new growth of the fourth crop caused moderate damage and some stickiness from the honeydew. The population was eliminated by a treatment with 1 ounce of Systox per acre on August 20. This treatment did not seriously affect a small population of Coccinellidae which were present in the field after the August 12 cutting. This population of coccinellids reproduced and were able to keep the spotted-alfalfa-aphid population from causing economic damage during the entire fourth cutting period. In combination with the effects of the September 18 cutting and a moderate population of *Chrysopa* larvae (0.2 per sweep), these lady beetles reduced the aphid population to low levels and it remained low for the rest of the year.

**Hanford.** In a Hanford field during the growth of the crop which was harvested on July 20, 1957, the spotted-alfalfa-aphid population reached a high level of 291 aphids per stem in the study area. A population of *Hippodamia convergens* and *H. quinquesignata punctulata* of approximately 1.8 larvae per sweep reduced this high population of aphids to 14 per stem on July 24 and to 1.6 per stem on July 30 (fig. 8). After the pupation of the very even brood of coccinellid larvae and a moderate flight of alate spotted alfalfa aphids into the area, the aphid population again began to increase. On the basis of higher populations in other portions of the field, the grower treated the entire field with 2 ounces of Systox per acre. This selective treatment did not upset the natural control in the study area, and the aphid population was held low for the remainder of the year by a combination of predators and the aphidiine parasite, *Praon palitans* Muesebeck. On September 18, the estimated parasitization was 43

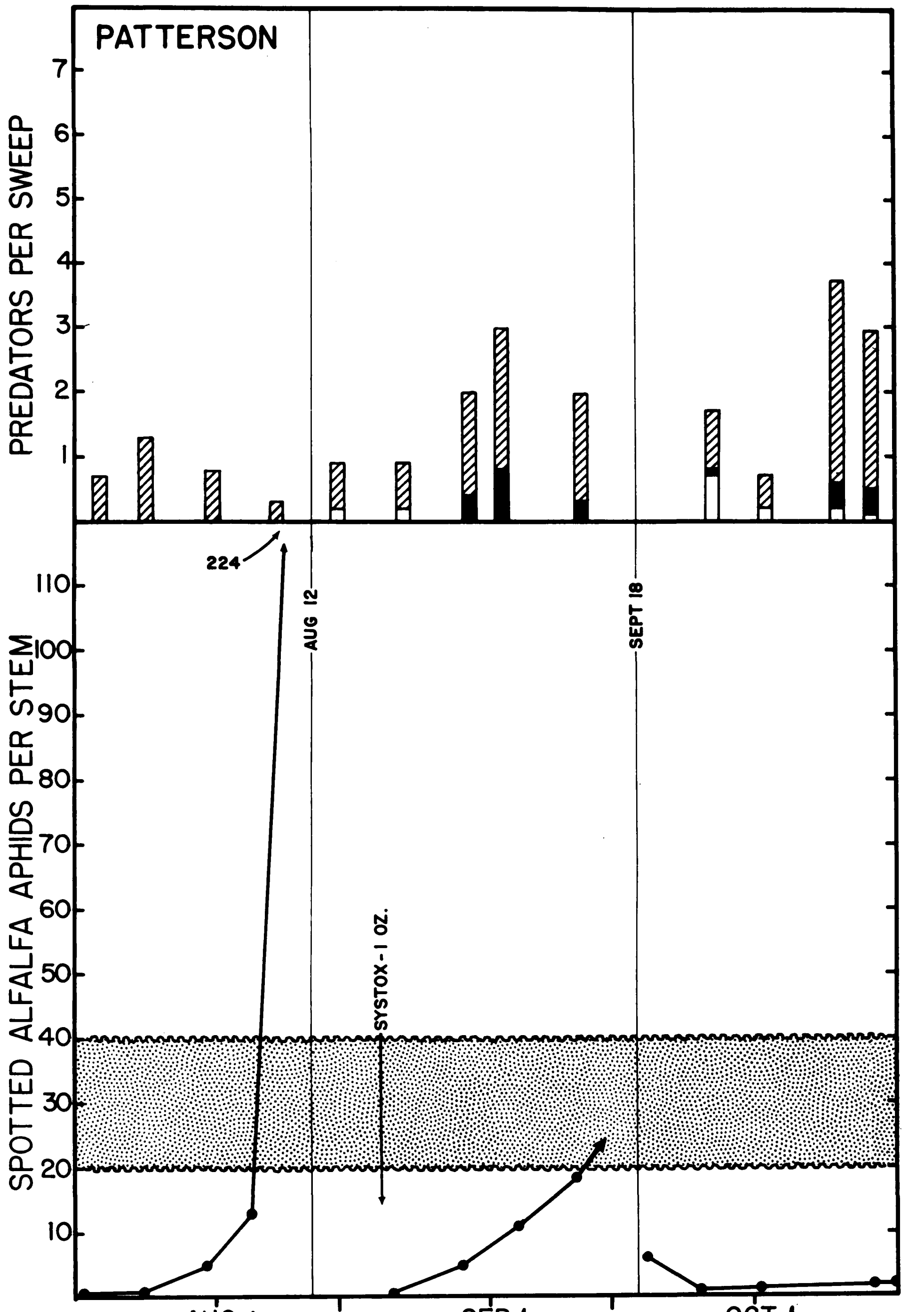


Fig. 7. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Patterson, Stanislaus County, 1957. Insecticidal treatment applied by air by commercial pest-control operator. Symbols as in fig. 1.

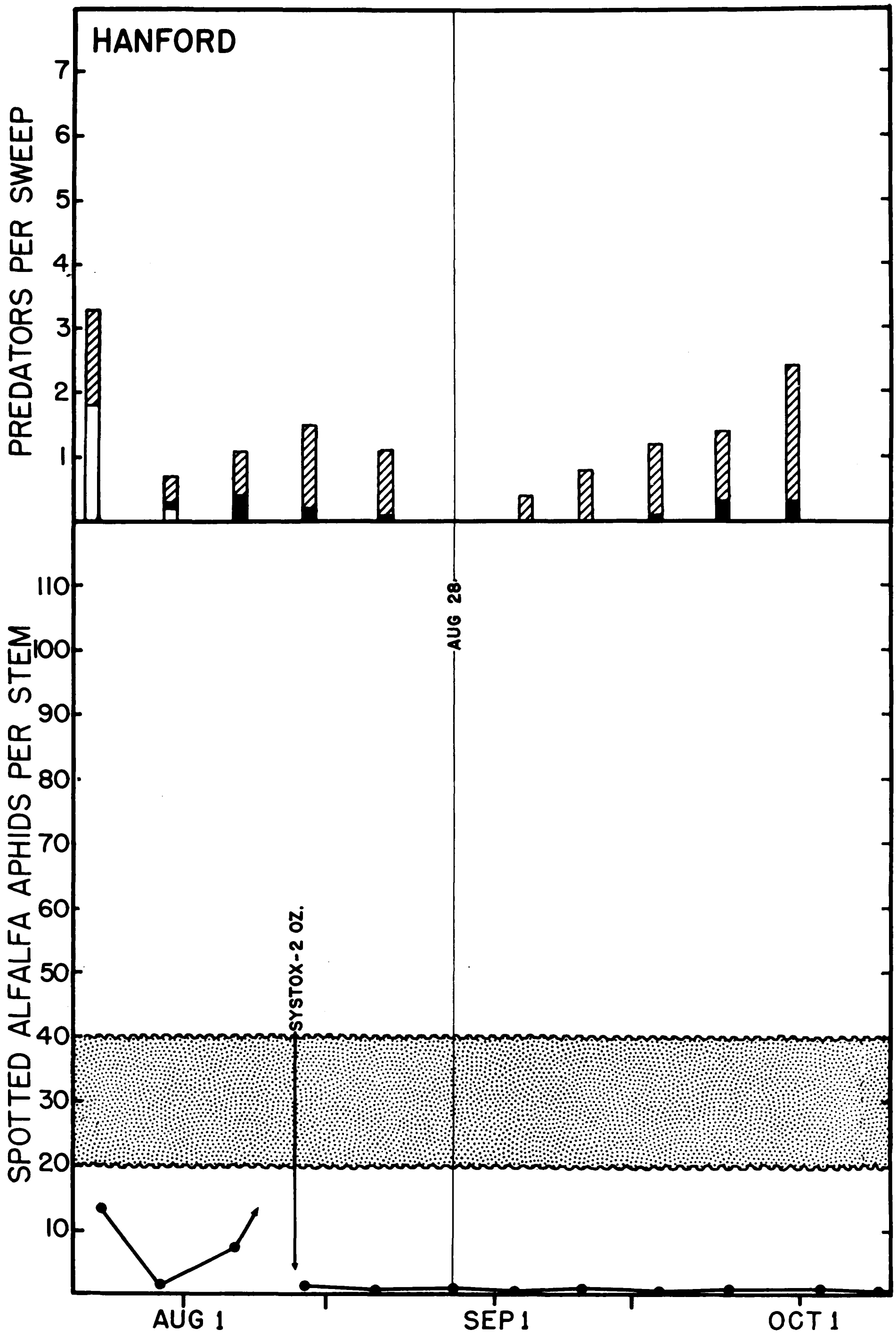


Fig. 8. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Hanford, Kings County, 1957. Insecticidal treatment applied by air by commercial pest-control operator. Symbols as in fig. 1.

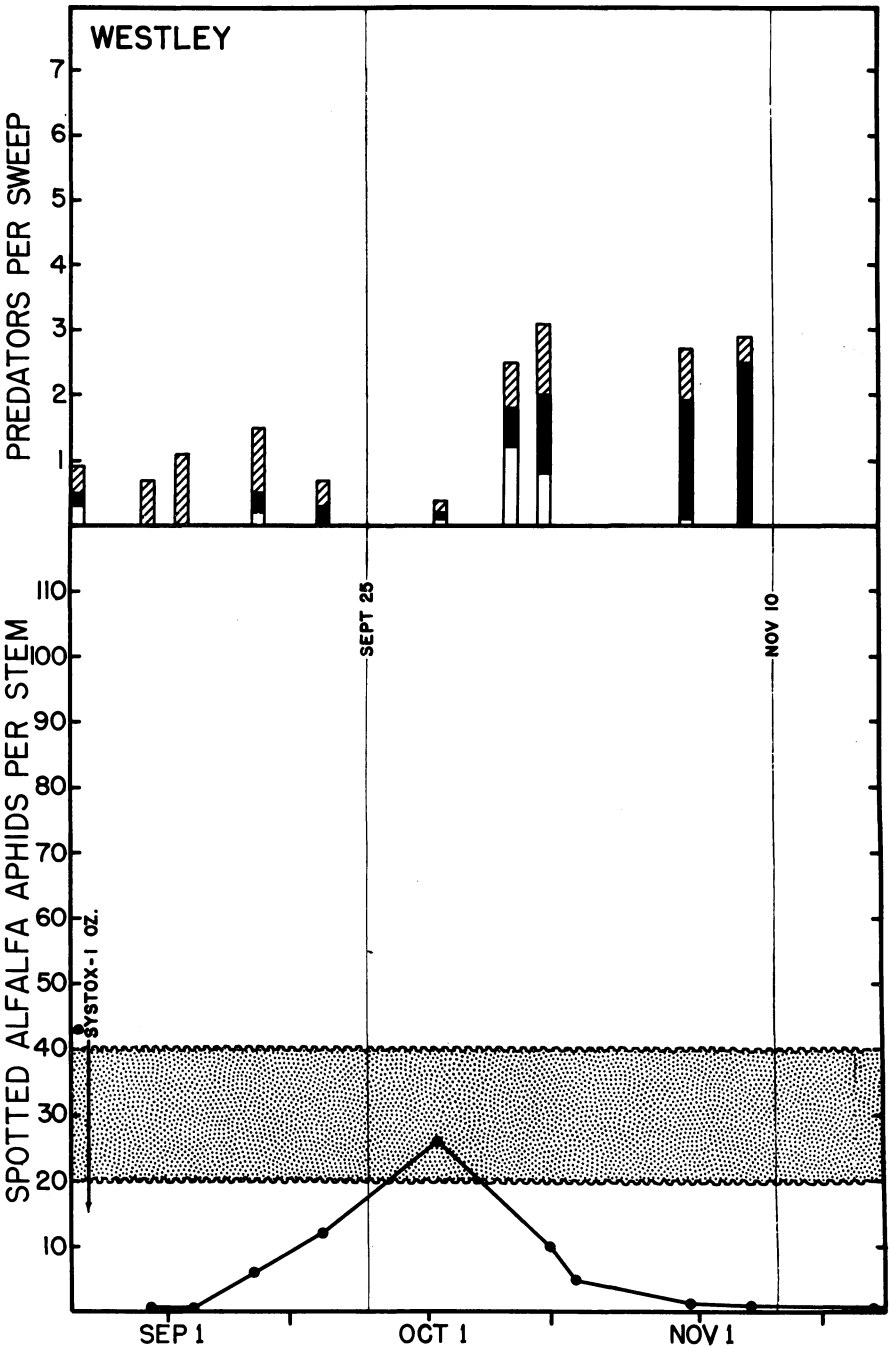


Fig. 9. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Westley, Stanislaus County, 1957. Insecticidal treatment applied by air by commercial pest-control operator. Symbols as in fig. 1.

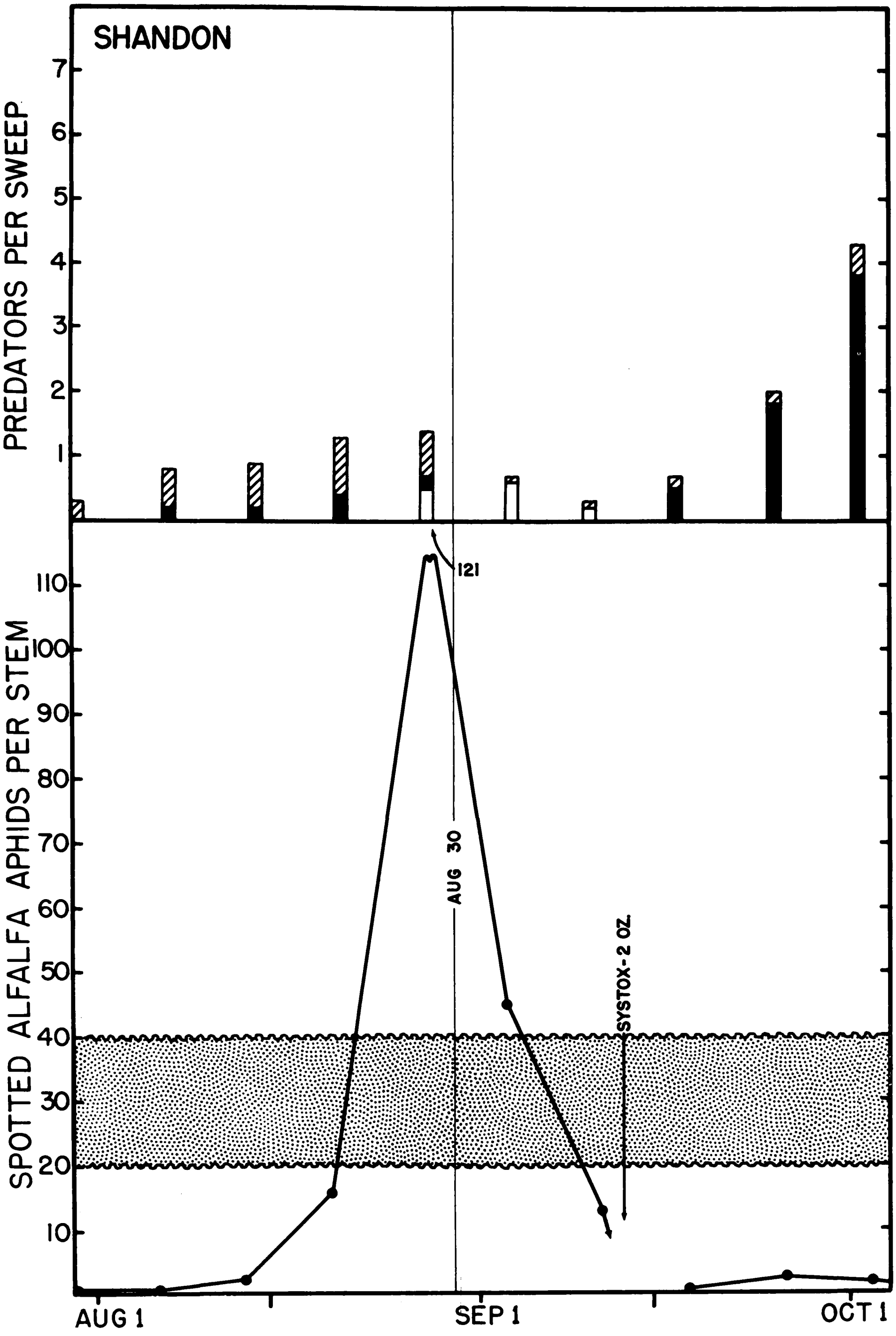


Fig. 10. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Shandon, San Luis Obispo County, 1957. Delayed insecticidal treatment applied by air by commercial pest-control operator. Symbols as in fig. 1.

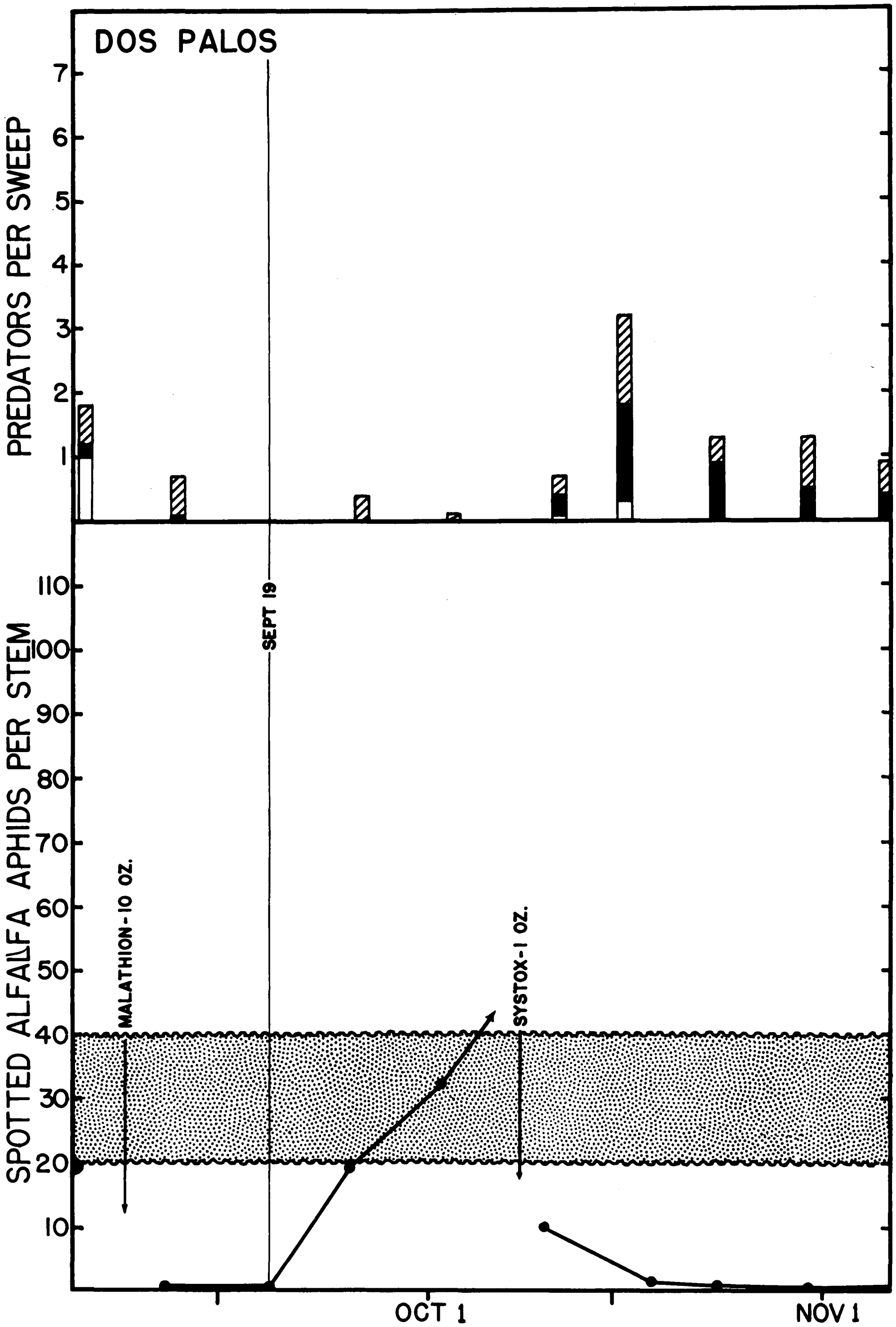


Fig. 11. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Dos Palos, Merced County, 1957. Insecticidal treatment applied by grower's ground sprayer. Symbols as in fig. 1.

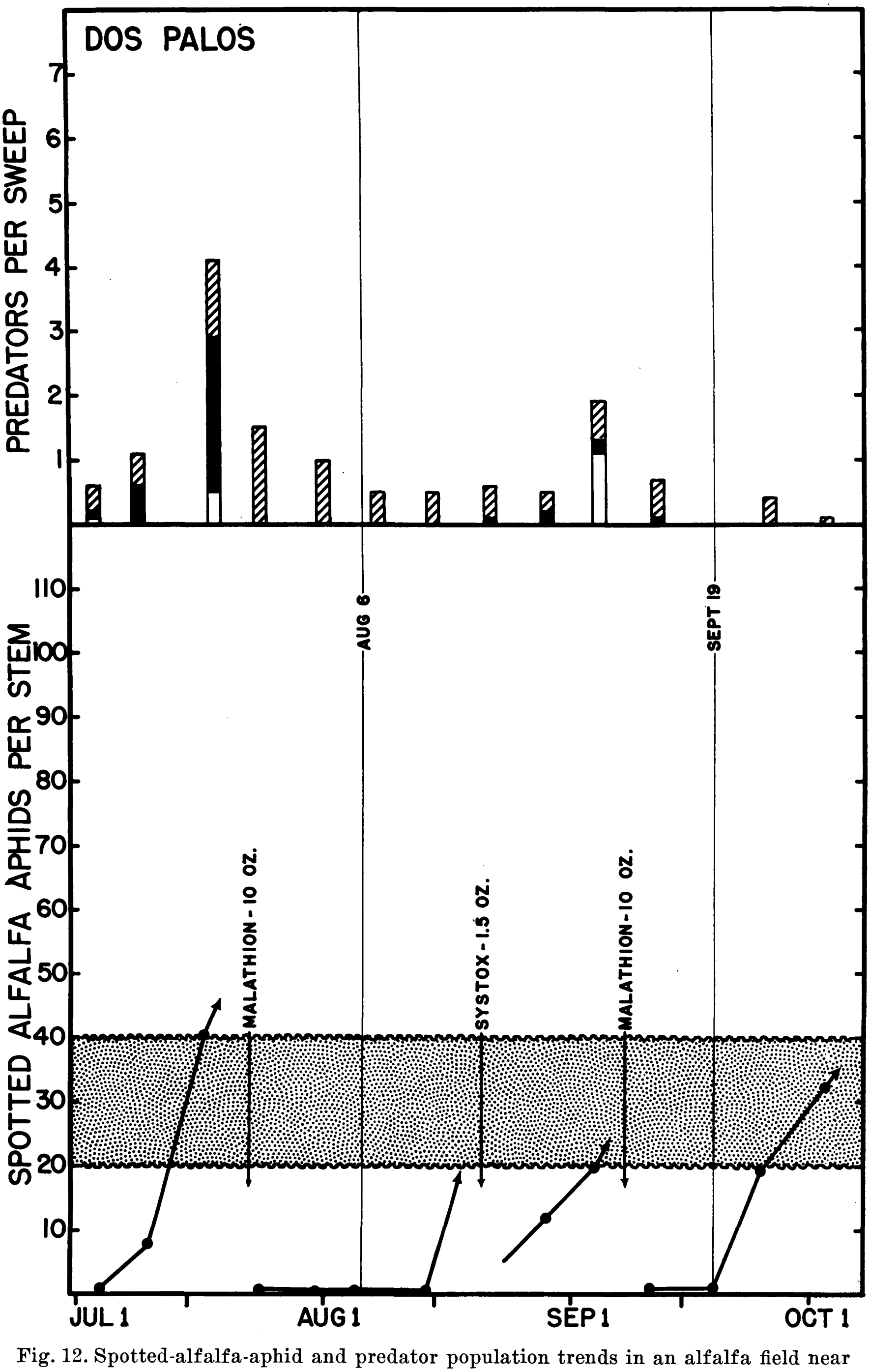


Fig. 12. Spotted-alfalfa-aphid and predator population trends in an alfalfa field near Dos Palos, Merced County, 1957. Symbols as in fig. 1.

per cent. On the same date the predators were represented by 6 lady-beetle adults, 112 *Nabis ferus,* and 2 *Geocoris* per 100 sweeps.

**Westley.** In mid-August, 1957, a large number of alate spotted alfalfa aphids moved into a Westley field. The moderate predator population responded to this invasion but was not able to cope with the rapid rate of increase of the aphid. A selective treatment with 1 ounce of Systox per acre on August 27 reduced the population of 42 aphids per stem to low levels (fig. 9). The number of predators sampled in the study area declined temporarily because of the low number of aphids and pupation of larvae. The predators increased slightly during the remainder of the cutting period. General observation in the field indicated that *Chrysopa* larvae were especially important here, but this was not adequately shown by the sweep counts. Apparently these larvae were more abundant in the lower parts of the plants, which were not sampled by the sweeps. Although predators were not high in September they were able to slow the rate of increase of the aphids and to increase themselves so that by October they dominated the situation and prevented the *Therioaphis* population from causing serious economic damage.

**Shandon.** In mid-August, 1957, after movement of alates into the study area, the spotted-alfalfa-aphid population started to increase (fig. 10). The moderate lady-beetle population responded to this increase and on August 28 reached a level of 21 adults and 47 larvae per 100 sweeps. These coccinellids were not able to prevent the aphid increase to a level of 121 per stem at harvest time (August 30). However, combined with the effects of the mowing of the crop, the coccinellid larvae, with the searching area reduced to the alfalfa stubble, were able to bring about a rapid decline in the aphid population. Unfortunately the grower, not realizing that the aphids were being eliminated in the stubble, made an unnecessary insecticidal treatment. Systox at 2 ounces per acre was applied by air on September 13. It is of special significance that this treatment did not disrupt the natural enemies present. Lady-beetle populations present in the field after the treatment held the aphid population low for the remainder of the season.

**Dos Palos.** During the fifth cutting period (fig. 11) this field was treated on September 8 by air with 10 ounces of malathion. This treatment was applied to eliminate a population of 19.5 spotted alfalfa aphids per stem; but it also eliminated a coccinellid population of 0.2 adult and 1.1 larvae per sweep. The adult coccinellids shown in the September 12 count were newly emerged beetles which soon disappeared, probably because the aphids had been eliminated.

After the harvest on September 19, the spotted-alfalfa-aphid population rose rapidly to treatment levels. In contrast to the malathion treatment in the previous cutting period, the use of 1 ounce of Systox favored biological control. Soon after the treatment, lady beetles moved into the area from other fields and held the population at a low level for the remainder of the season.

The use of a selective insecticide will not be as spectacular in its effects on the aphid population as in the cases cited above if biotic agents are not present to continue the suppression of the pest population. The situation in this field during July, August, and September, 1957 (fig. 12) illustrates this point. In this field on July 23, a nonselective treatment with malathion eliminated a coccinellid population of 2.4 adults and 0.5 larva per sweep. The other predators were largely *Nabis* and were not seriously affected. In mid-August the spotted-alfalfa-aphid population again rose rapidly, and on August 21 the field was treated with 1½ ounces of Systox per acre. A population of 0.1 lady-beetle adult per sweep was able to survive and reproduce after this treatment. However, the resultant brood of coccinellid larvae of about 1 per sweep was not able to cope with the large flight of alates which moved into the field on about September 1. The field was treated with malathion and again the coccinellids were eliminated. In the following cutting period the aphid population rose rapidly after the harvest of the crop. (Compare with figs. 7, 8, and 9).

## CONCLUSIONS

In the Central Valley of California, native aphid predators are significant factors in holding populations of the spotted alfalfa aphid below economic levels for much of the growing season (figs. 1 and 2). In other alfalfa-growing areas they are capable of holding the aphid populations below economic levels throughout the year. The Coccinellidae, especially the genus *Hippodamia,* are the most important of these predators, although species of *Chrysopa, Nabis, Geocoris,* and larvae of certain syrphid species may be important at certain times in some fields.

Insecticidal treatments are necessary to keep the spotted-alfalfa-aphid populations below economic levels during the times of the year when biological control is inadequate. Such necessary insecticidal treatments should be designed to throw the balance back in favor of the biological control. Insecticides if used unwisely will eliminate the predators present in a field and thus will often produce a situation which requires repeated treatments. Treatment by schedule without reference to the insect populations (fig. 4) is particularly hazardous. Such treatment schedules bring on the development of resistant strains of insects and can cause increases in other pests. At the same time there is no evidence that such attempts to hold the spotted alfalfa aphid at very low population levels produce profitable increases in the yield or quality of hay.

Treatments with nonselective materials such as malathion and parathion eliminate or drastically inhibit the natural control, but this use does not always result in an immediate resurgence of the spotted-alfalfa-aphid populations. Where such treatments have been properly applied and the aphid populations reduced to low levels, the populations, in the absence of heavy flights of alates, recover slowly. If, on the other hand, there are heavy flights of alates into the field, the population will, in the absence of natural control, increase rapidly to high levels. In some instances where plant growth conditions are unsatisfactory, rapid resurgence will not occur under any circumstances.

Treatments with selective insecticides such as Systox will, in general, by preserving natural enemies, have the effect of throwing the balance back in favor of the natural enemies. Such selective treatments should be applied whenever the aphid population reaches the economic threshold, regardless of the existing status of natural enemies in the fields. The use of a selective insecticide will not, however, insure any longer-lasting control of the aphids than a nonselective material if no natural enemies are present.

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## LITERATURE CITED

DICKSON, R. C., E. F. LAIRD, JR., and G. R. PESHO
1955. The spotted alfalfa aphid (yellow clover aphid on alfalfa). Hilgardia **24**(5):93–118.

GRAY, K. W., and J. SCHUH
1941. A method and contrivance for sampling pea aphid populations. Jour. Econ. Ent. **34**(3):411–15.

HAGEN, K. S., and RAY F. SMITH
1958. Chemical and biological methods of pest control. Agr. Chem. **13**(7):30–32, 89–92.

SMITH, RAY F., and K. S. HAGEN
1956. Enemies of spotted alfalfa aphid. California Agr. **10**(4):8–10.

STERN, V. M., and R. VAN DEN BOSCH
1959. Field experiments on the effects of insecticides. Hilgardia **29**(2):103–30.

STERN, V. M., R. VAN DEN BOSCH, and D. BORN
1958. New control for alfalfa aphid. California Agr. **12**(1):4–5, 13.

VAN DEN BOSCH, ROBERT
1956. Parasites of alfalfa aphid. California Agr. **10**(10):7, 15.
1957. The spotted alfalfa aphid and its parasites in the Mediterranean region, Middle East, and East Africa. Jour. Econ. Ent. **50**(3):352–356.

VAN DEN BOSCH, R., E. I. SCHLINGER, E. J. DIETRICK, K. S. HAGEN, and J. K. HOLLOWAY
1959*a*. The colonization and establishment of the imported parasites of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) in California. Jour. Econ. Ent. 52(1):136–41.

VAN DEN BOSCH, R., E. I. SCHLINGER, E. J. DIETRICK, and I. M. HALL
1959*b*. The role of imported parasites in the biological control of the spotted alfalfa aphid in southern California in 1957. Jour. Econ. Ent. **52**(1):142–54.

4*m*-10,'59(A0816)MR

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