undetermined temperature between 30°C and 35°C prolonged the developmental period. The deleterious effect of high temperature partially explains the low populations of boll weevils in Arizona in midsummer. Fluctuating temperatures did not increase the time required for the development over that required at a constant temperature if the heat input was similar and the temperatures did not exceed 30°C.

Populations of thurberia weevils in the mountainous areas were extensive wherever thurberia cotton fruited freely. Laboratory studies showed that these weevils could survive the winter outside the hibernation cells if proper amounts of moisture were provided. However, a large percentage of the weevils that remained in their cells were still alive when the released weevils were dead. The time for development of thurberia weevils ranged from 72.5 days at 15°C to 17.5 days at 30°C.

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## BIOLOGICAL CONTROL INVESTIGATIONS

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### Objective

To determine the feasibility of using native and introduced parasites and predators to control insects damaging cotton.

### Summary of Progress

Studies of tachinid parasites of *Heliothis spp.*, indicated that mean total developmental periods required for *Carcelia illota* (Curran) ranged from 78.5 ± 8.5 days at 15°C to 18.3 ± 1.9 days at 30°C. The mean number of puparia per host larvae [*Heliothis virescens* (F.), tobacco budworm] was 3.3 - 3.5. Survival of the puparia at higher temperatures was poor, and the time required for development varied widely at all temperatures. The total time for development of *Eucelatoria armigera* (Coquillett) in bollworms, *Heliothis zea* (Boddie), ranged from 49.4 ± 2.4 days at 15°C to 10.7 ± 0.7 days at 30°C, compared with 46.6 ± 3.0 days at 15°C and 11.1 ± 0.6 days at 30°C in the tobacco budworm. In both hosts the periods were slightly longer at 32.2°C, and none of the parasites reached adulthood at 35°C. Thus, on the basis of time required for development of parasites, successful fly emergence and ease of host rearing, the tobacco budworm proved to be the most efficient host at 30°C.

The time required for Microplitis croceipes (Cresson) to develop from egg to pupae varied from 34.5 $\pm$ 3.6 days at 15°C to 7.3 $\pm$ 0.6 days at 32.2°C. At 15°C, all the parasites diapaused, and at 35°C all the parasites died. Pupal periods ranged from 12.2 $\pm$ 1.7 days at 20°C to 6.6 $\pm$ 0.8 days at 30°C. Diapausing parasites emerged when they were held at 25-30°C. Sex ratio was determined by the rearing temperature with a 1:1 ♂:♀ ratio obtained at 25°C, and 2:1 ratio at 30°C.

The lacewing, Chrysopa carnea (Stephens), was studied intensively in 1968. The duration of the egg stage was found to vary from 6.4 days at 68°F to three days at 95°F. The larval stage varied from three weeks at 68°F to one week at 86°F with each larval instar lasting two-four days, the first generally being the longest. The pupal stage varied form 13-14 days at 68°F to 6-7 days at 86°-95°F. Studies of the searching capability of the larvae showed that first instar larvae consumed 6.7 eggs per day, and second and third instar larvae consumed about seven times this number. In a more complex topography, three-six eggs per day were consumed by older larvae.

In the field studies that followed successful laboratory tests, sprays of feed Wheast®, honey, glycerine, and water increased the populations of adult Chrysopa in treated areas 2.7 to 7.8-fold over those in untreated areas. However, no consistent increase in the number of eggs laid was observed. Successful methods of applying Chrysopa eggs were developed; however laboratory studies showed that the eggs must be applied late in the evening, not earlier than one hour before sundown, if the high temperatures of the soil surface that cause high mortality are to be avoided. Introductions of Chrysopa eggs at the rate of several thousand per acre failed to increase the large natural population already present.

Laboratory and field-dispersal studies indicated that the strain of Trichogramma minutum Riley, an egg parasite, being considered for biological control was short-lived, of low fecundity, and dispersed poorly. The wasps were apparently vulnerable to high temperatures both as adults and as adults emerging from host eggs placed on hot soil. In ideal conditions the wasps searched rapidly and oviposited freely but when the complexity of the searching arena was increased or the temperature raised their efficiency declined markedly. The wasps apparently searched the upper portions of artificial plants, which indicates that their search pattern is well correlated with the location of host eggs on cotton plants in the field. Emergence tests indicated that suitable patterns of emergence could be developed by introducing immature wasps of proper age into centralized release stations. The wasps showed no preference among eggs of bollworms, tobacco budworms, cabbage loopers, (Trichoplusia ni (Hübner), and beet armyworm, Spodoptera exigua (Hübner), when the eggs were offered at the same time, but oviposition in eggs of the saltmarsh caterpillar, Estigmene acrea (Drury), and the pink bollworm was accomplished only when it was forced.

Laboratory and cage tests of Bracon kirkpatricki (Wilkinson) as a biological control agent for the pink bollworm were promising. In the laboratory five adult parasites were obtained from each parasitized pink bollworm. In the greenhouse, two pairs of parasites per plant parasitized an average 63% of the available pink bollworms on each plant. In a cage test, the wasps released at a rate of 20,000-24,000 pairs per acre effectively parasitized

75-80% of the pink bollworms in squares and blooms over a 13-day period. However, the length of the ovipositor indicates that the female will only be effective against pink bollworms in squares and blooms.

Anaphes ovijentatus (Crosby and Leonard), an egg parasite of lygus bugs, common in alfalfa fields in Arizona but not in cotton fields, is easily reared on any of several host eggs including Spissistilus festinus (Say). Newly emerged females contain an average of about 50 eggs. Unfertilized females produce male offspring, and fertilized females produce offspring of both sexes. Although the females parasitize eggs of Lygus hesperus (Knight), they parasitize fewer as the age of the host eggs increase. One parasite develops from each host egg.

In laboratory and cage studies with Geocoris punctipes (Say), predation by G. punctipes was extremely difficult to assess. However, when G. punctipes were applied in cages at the rate of 100/sq. ft., populations of aphids, nymphal lygus bugs, and Spissistilus festinus were reduced somewhat. Animal food is essential to the development of the G. punctipes, but they also utilize plant food. These predators are apparently more omnivorous than was previously believed and their predaceous activities may be opportunistic in nature. However, when large numbers were placed together in small containers, no cannibalism resulted. Therefore, with suitable conditions, large numbers of G. punctipes may be reared in a small space.

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## EVALUATION AND AUGMENTATION OF BIOLOGICAL CONTROL AGENTS TO REPLACE OR SUPPLEMENT THE USE OF PESTICIDES

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### Objectives

A. To assess the influence of environmental factors, both natural and artificial, on the effectiveness of parasites, predators, and pathogens in suppressing pests.

B. To determine the differential effects of selected insecticides on the internal parasites of lepidopterous larvae.

### Summary of Progress

Topical applications of Sevin® on salt-marsh caterpillar larvae--averaging slightly over 600 mg. per larva--resulted in an $LD_{50}$ of approximately 700 µg per larva. This depended somewhat upon the location from which the colony was established. However, more data are needed to determine the variability in susceptibility to Sevin of salt-marsh larvae collected from different areas.