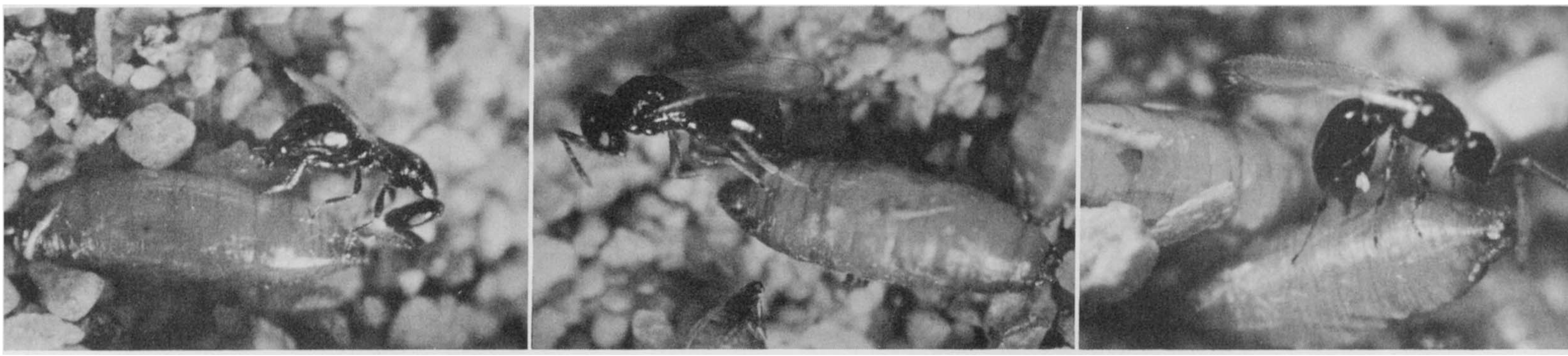


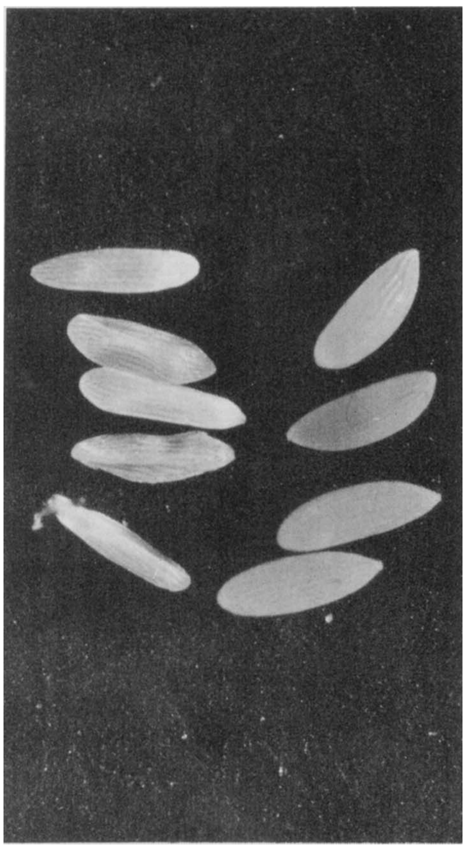
Parasitoids that attack *Hippelates collusor* pupae in the soil in the Coachella Valley of California: *Spalangia drosophilae* (to left), *Eupteromalus hemipterus* (center), and *Phaenopria occidentalis* (right).

E. F. LEGNER · E. C. BAY

Dynamics of *Hippelates* Eye Gnat Breeding in the Southwest

NON-CULTIVATION AND COVER

Collapsed (left) and turgid (right) viable eggs of *Hippelates collusor*. The collapsed eggs assume the shape of the turgid eggs in 2 to 5 minutes after being wet with water



THERE ARE PRESENTLY SEVEN SPECIES OF *Hippelates* eye gnats which are adapted to varying climatic situations in California and southwestern United States. One species, *Hippelates collusor* (Townsend), is of wide-spread concern because it has become well adapted to year-around breeding in the hot interior agricultural areas of the Southwest, where field cultivation is practiced. *Hippelates pusio* Loew, also an agricultural breeder, is more restricted to the cooler climatic conditions on the coast. Two species, *Hippelates robertsoni* Sabrosky, and a recent invader from Mexico, *H. impressus* Becker, inhabit the mountains or lowlands in the spring. They cannot tolerate the extreme heat of summer in the lowlands of this region. Species that are of little annoyance or whose density is extremely low are *H. microcentrus* Coquillett, *H. dorsalis* Loew and *H. hermsi* Sabrosky.

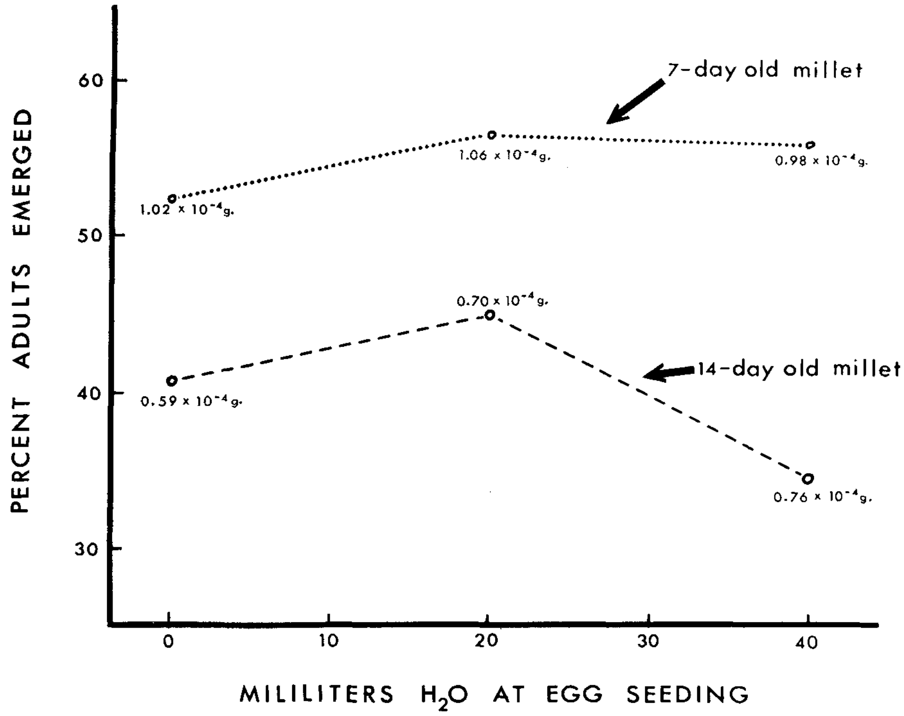
The public health importance of *Hippelates collusor* has made this species the object of intensive scientific research for over 40 years in California. Considerable information has been gathered on its flight range, distribution, breeding habits and natural enemies. Effective means of reducing its pest status are known, but a better understanding of gnat ecology is required than most agriculturists possess. A unified community-wide effort is necessary to permanently abate the *Hippelates* problem.

Most data in this study has been gathered on *Hippelates collusor*, but much of this information also applies to other species. The mature mated female gnat obtains most of her protein for ovigenesis by feeding on the exposed mucous of animals, principally around the head. Although many mucous-producing farm animals or wildlife suffice for this purpose, even frogs and humans are frequently chosen as feeding sites.

A day or two after feeding, the female gnat is prepared to lay eggs. Oviposition may occur on moist ground or on herbage close to the soil. Under natural conditions without irrigation and with few consequent oviposition sites, the female's capacity of 80–100 eggs is seldom laid. Most of her time is spent seeking out the few green shoots of plants produced from winter rains. Under primitive natural conditions breeding is probably largely restricted to early spring. Eggs that are laid but which do not receive enough soil moisture to hatch, undergo partial dehydration, remaining physiologically active until a summer rain causes some of them to hatch, sometimes months later (see photo of eggs). The larvae then are able

Non-cultivation, emphasized by scientists for over 40 years, is still recognized as the principal requisite to gnat abatement. However where cultivation is required (as in certain row crops), it should be conducted at night, or on days when either the temperature is below 65°F or while wind velocities exceed 2 m.p.h.—all times when gnats are inactive. Exposure of the cultivated soil to the open air makes it progressively unattractive to ovipositing females. In orchards, mature hardened-off cover plants are preferred, which can be kept low by mowing. Cutting does not interfere with the populations of soil predators and is not very attractive to eye gnat oviposition. Reducing the adult eye gnat population through the use of poison baits or aerosol insecticides should be recognized as advantageous in cases of localized gnat abundance (golf courses, residential areas, etc.), and not harmful to the processes of natural reduction. A unified, community-wide effort is necessary to permanently abate the gnat problem.

EMERGENCE AND AVERAGE OVEN-DRY WEIGHT OF HIPPELATES COLLUSOR ADULTS FROM 236-cc CONTAINERS SUPPORTING THE GROWTH OF 7- AND 14-DAY-OLD MILLET SEEDLINGS AFTER AN INOCULATION OF 100 EGGS.



CROPS OFFER BEST CONTROL

to feed on the dead but resaturated organic matter in soil. This safeguard enables some gnats to exist in a developmental state throughout the long hostile heat of summer, and permits emergence and egg laying by newly emerged females again in the cooler months of autumn and winter.

With the advent of cultivation and irrigation, egg laying sites were tremendously increased and seemingly optimum breeding conditions prevailed the year round. The new circumstances under agriculture do not favor *Hippelates* as much as it might appear, however. Certain natural biological restrictions operating under the new conditions have resulted in an estimated destruction of over 95 per cent of all developing gnat larvae, and further mortality was incurred by the pupae.

Under agricultural conditions where the soil is not disturbed (as in some citrus and date orchards), irrigation water permits the abundant production and germination of grass and weed seeds. This condition is a stimulus to eye gnat oviposition while the plants are young, but this gradually diminshes as plants age (after 2 to 3 weeks). Older plants are also less suitable for larval development (see graph). Many eggs are laid on young emerging vegetation, which give rise to a high density of *Hippelates* larvae. These larvae feed on the roots of the young plants until crowded conditions force them to migrate out into the surrounding watered soil in search of less congested feeding sites. Because the larvae are very small and the plant roots are comparatively sparse, most larvae die before ever locating another feeding site. They are further handicapped by their inability to take a straight course, which lengthens the trip. Their death comes about through either starvation or predation by other insects, such as the staphylinids, *Platystethus* and *Philonthus*, the carabids, *Agonoderus maculatus* LeConte, *Amara californica* De Jean and *Anisodactylus californicus* De Jean; and the predatory earwig, *Euborellia annulipes* (Lucas).

Those larvae that are fortunate enough to have ample food for development, then become targets for attack by a group of tiny wasp-like parasitoids, *Hexacola* species. These wasps locate their host larvae by guiding on the plant stems which lead them to the roots where the larvae are feeding. Larvae that survive the attack of *Hexacola*, pupate in loose soil adjacent to the roots where they fed. Here they are attacked by another group of parasitoids, the Diapriidae, Pteromalidae and Staphylinidae, which contain several native species, *Phaenopria occidentalis* Fouts, *Spalangia drosophilae* Ashmead, *Eupteromalus hemipterus* (Walker) (see photo sequence of parasitoids), and *Aleochara* sp. Efforts by the Division of Biological Control at Riverside have resulted in the importation of additional parasitoids from the West Indies which include two new strains of *Spalangia drosophilae*, *Trichopria* nov. sp., and *Hexacola* sp. near *websteri* (Crawford). It has been estimated that at least 97 per cent of the developing gnats in non-cultivated fields are now being killed during the summer months by a combination of these physical and biotic factors. Resultant gnat populations, although more numerous than under the primitive pre-agriculture era, are still very low and do not become a widespread nuisance. Maximum average yields per yard square of soil range up to about 0.6 adult gnats.

When agriculture involves cultivation, a third set of circumstances is produced which positively favors gnat production. In the first place, the cultivated soil produces a strong ovipositional stimulus to mature females that causes them to lay many more eggs than they would under the two previously cited examples (table 1). This soil stimulus last several hours after cultivation. Secondly, a great quantity of food in the form of stems and leaves of plants is incorporated into the soil by cultivation which reduces the crowding effect and increases the chances of any migrating larvae to locate new feeding sites. Third, the soil predator population, although not being significantly changed (table 2), has a greater difficulty in encountering non-migrating individuals; and fourth, parasitoids are handicapped in their location of larvae or pupae in the disrupted habitat (table 3). Survival of larvae under these conditions is greatly enhanced, giving rise to maximum average yields of over 30 adults per yard-square of soil after every cultivation. Every time the cultivated soil is irrigated, some female gnats are attracted for oviposition, and their larval progeny find abundant food available.

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TABLE 1. ADULT OFFSPRING OF 250 HIPPELATES COLLUSOR FEMALES OVIPOSITING ON MILLET IN LABORATORY AND FIELD

Condition of millet at oviposition	Irrigation	Mean no. adult offspring	
		Laboratory*	Field†
Growing	Only sufficient water to sustain turgid plants	23.9	55.8
	Water-saturated soil	29.8	51.8
Mixed into soil	Only sufficient water to sustain turgid plants	70.4	186.4
	Water-saturated soil	32.3	137.0

* 6 replicates in each of 2 cages.
† 5 replicates in 5 separate field tents.

TABLE 2. MEAN NUMBER OF SOIL PREDATORS IN CULTIVATED AND NON-CULTIVATED SOL SUPPORTING THE DEVELOPING STAGES OF HIPPELATES COLLUSOR AT THERMAL, CALIFORNIA*

Predator Group	Average no. per yard-square and depth of 6-inches†	
	Uncultivated	Cultivated
COLEOPTERA		
Carabidae		
Agonoderus maculatus LeConte	32.74	35.08
Staphylinidae		
Larvae	2.34	9.35
Adults	720.40	484.16
DERMAPTERA		
Euborellia annulipes (Lucas)	4.67	4.67
HYMENOPTERA		
Formicidae	44.44	51.44

* Weed control in the non-cultivated orchard was performed by cutting.
† Average of 10 semi-monthly sample dates from June through November 1968, estimated from 6 inch core samples with a 1 inch diameter, processed in Berlese funnels.

TABLE 3. PARASITIZATION OF HIPPELATES COLLUSOR LARVAE BY 10 HEXACOLA SP. FEMALES IN INOCULATED 236-CC CONTANERS WITH MILLET IN CAGES AT 25°C

Condition of Millet at Oviposition	Inoculated Egg Density	Adult Hippelates Emerged	Parasite Emergence
	%	%	%
Growing	50	36.4	3.2
	100	32.5	3.8
Tilled in soil	50	57.2	0.5
	100	60.7	0.1

Hybrid vigor estimates for backcross of crisscross breeding involving Angus and Hereford

CROSSES BETWEEN THE Aberdeen Angus, Hereford and Shorthorn breeds are becoming increasingly popular in the production of market calves—reflecting (in part) the impact of recently published results of experiment station trials of two-way and three-way crosses.

If a producer elects to crossbreed, he is faced with the question of how to obtain his replacement heifers. When crossing two breeds, one systematic way to obtain replacement heifers is to crisscross. Crisscrossing is a system in which a heifer sired by a bull of one of the breeds (if kept for replacement purposes) will always be bred to a bull of the other breed.

Under such a system the brood cows and calves produced after several cycles will carry about two-thirds the blood of one breed and one-third the blood of the other or vice versa. In the first backcross, however, the calves will have one-quarter the blood of one breed and three-quarters of the other, or vice versa.

First backcross

Little information has been reported to date on the amount of hybrid vigor exhibited by the first backcross calves. This report presents some such estimates. As shown in table 3, the average of the reciprocal backcross (backcross calves out of F_1 mothers) is 8.1% superior to the average of the straightbreds (straightbred calves out of straightbred mothers) for per cent calf crop weaned, and 9.7% better for pounds of calf weaned, per heifer exposed to a breeding bull. That is to say, the same genetic resources (the Aberdeen Angus and Hereford breeds) when used in this stage of the crisscross system are estimated to be about 10% more efficient than when used in straightbreeding (for traits associated with weaning).

Raw data for similar crosses of the Aberdeen Angus x Shorthorn and Hereford x Shorthorn as well as for Aberdeen Angus x Hereford breeds are presented in Tables 1 and 2.

Three calf crops were calved and reared to weaning at the University of California Sierra Foothill Range Station near Marysville. The breeding plan is shown in table 1. The breeding heifers were produced in the University of California crossbreeding trials at Davis.

In the design of the trials, (tables 1 and 3) systematic sire and year effects cancel out in the hybrid vigor estimates presented in table 3.

Hybrid vigor

No hybrid vigor estimates are given for the Aberdeen Angus x Shorthorn or Hereford x Shorthorn crosses because of the lack of data for the third calf crop (nine breeding heifers involved in plans to produce the third calf crop were lost during the experiment through accidental poisoning). However, raw data for all of the 2-way crosses are given (tables 1 and 2) since they can yield useful information when combined with similar data from trials at other places.

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An F_1 (Angus × Hereford) heifer being scored for meatiness with rump gage.