festation in the years with a dry August and September and more in normal rainfall years. Probably very high moisture will kill newly hatched larvae by pathogens or otherwise. In damp soil larvae can establish on deeper roots. A few larvae were found in the field in roots at a depth of 1 ft.

Larvae and some pupae were attacked by a white muscardine fungus, *Beauveria bassiana* (Balsamo), and green muscardine fungus, *Metarrhizium anisopliae* (Metchnikoff), both in the laboratory and field. The same fungus pathogens were reported by Clark and Enns (1964). Some larvae in the field were killed by a hymenopterous parasite, *Bracon caulicola* (Gahan). The fungi were determined by Dr. George O. Poiner, Berkeley, Calif., and the parasite by Dr. Reece I. Sailer, Systematic Entomology Laboratory, Agr. Res. Serv., USDA, Washington, D.C.

Rainfall had an effect on the period of moth emergence. In 1967, the total rainfall in June through August was 6.59 in. and the period of moth emergence was 29 days. In 1968, the total rainfall in these months was 11.61 in., and emergence occurred in 64 days. Maximum emergence occurred during dry periods. Similar observations were made by Clark and Enns (1964).

REFERENCES CITED

Atwood, V. F., and W. D. Wylie. 1963. Grape root borer threatens vineyards. Arkansas Farm Res. 12 (3): 6.

Brooks, F. E. 1907. The grape vine root borer. W. Va. Agr. Exp. Sta. Bull. 110: 19–30.

Clark, G. N., and W. R. Enns. 1964. Life history studies of the grape root borer (Lepidoptera: Aegeriidae) in Missouri. J. Kans. Entomol. Soc. 37: 56–63.

Mackay, M. R. 1968. The North American Aegeriidae (Lepidoptera): a revision based on late instar larvae. Mem. Entomol. Soc. Can. 58: 112 p.

Quaintance, A. L., and C. L. Shear. 1921. Insects and fungus enemies of the grape. USDA Farmers Bull. 1220: 43–45.

Riley, C. V. 1871. Third report on the noxious and beneficial insects of Missouri, p. 75–77.

Sarai, D. S. 1970. Effect of burial of grape root borer pupae on adult emergence. J. Econ. Entomol. 63: 1507–8.

Colonization and Release of *Tetrastichus haitiensis*[1] as a Biological Control Agent for Citrus Root Weevils[2,3]

R. A. SUTTON, A. G. SELHIME, and WILLIE MCCLOUD

Entomology Research Division, Agr. Res. Serv., USDA, Orlando, Fla. 32803

ABSTRACT

Over 86,000 adults of the parasite *Tetrastichus haitiensis* Gahan were reared successfully in the laboratory on eggs of *Diaprepes abbreviatus* (L.) and released in Florida in 1969 as possible control agents against *D. abbreviatus*, a West Indian pest of sugarcane and citrus recently discovered in Florida. This parasite also developed readily in the laboratory in eggs of the citrus root weevil, *Pachnaeus litus* (Germar), and of *P. opalus* (Olivier).

An infestation of *Diaprepes abbreviatus* (L.), a serious pest of citrus and sugarcane in the West Indies, was discovered in the vicinity of Apopka, Fla., in September 1968 (Woodruff 1968). Efforts to eradicate the infestation which were initiated immediately by Federal and State regulatory agencies included heptachlor granules applied as a soil treatment at a rate of 3 lb AI/acre, and foliage sprays of carbaryl applied aerially at a rate of 2 lb/acre every 10 days.

Meanwhile, attention was given also to establishing bilogical control agents against the weevil. Wolcott (1948) reported that *Tetrastichus haitiensis* Gahan was a major parasite of *D. abbreviatus* in Puerto Rico (Woodruff 1964) and that the parasite was most abundant there in May and June. Therefore, B. D. Burks, Systematic Entomology Laboratory, and A. G. Selhime, Fruit Insects Research Branch, Entomology Research Division, Agr. Res. Serv., USDA, collected egg masses of *D. abbreviatus* in Puerto Rico during late May and early June 1969 and inspected them for parasitization by *T. haitiensis*. Egg masses parasitized by *T. haitiensis* were identified readily and distinguished from normal (unparasitized) eggs, which remain a creamy ivory color. As the solitary parasite develops within the egg, the parasite's larva gradually darkens and is black when it matures to pupal form. This can be observed through the chorion. *Brachyufens osborni* (Dozier), which also develops as a solitary internal parasite, causes the host's egg to become clouded, and the developing parasite is difficult to see through the chorion. Other parasitic species occur as external parasites feeding among the eggs.

Some *B. osborni* were included in the material sent back to Florida from Puerto Rico by the collectors, but no attempts were made to release or colonize this species, since it was reported from eggs of *Pachnaeus* spp. in Florida. However, several hundred adult *T. haitiensis* were reared from the material, and these adults were the nucleus for the colony established at the laboratory at Apopka. This paper reports the rearing procedures and release efforts.

MATERIALS AND METHODS.—Adult parasites were confined in plastic vials with screen inserts in the base for ventilation. Food consisted of a few strands of excelsior previously soaked in a solution of honey and water and dried. However, female parasites were also observed to insert their ovipositors in weevil eggs and then turn to feed at the puncture sites. No free water was offered. Field-collected adults of *D. abbreviatus, Pachnaeus litus* (Germar), *P. opalus* (Olivier), and *Artipus floridanus* Horn were held in the laboratory for oviposition. Egg masses from these weevils were placed in vials with adult parasites. After sufficient time was allowed for stinging, the egg

[1] Hymenoptera: Eulophidae.
[2] Coleoptera: Curculionidae.
[3] Received for publication Feb. 2, 1971.

were removed and held in other plastic vials ice cream emergence tubes. The colony of para- was maintained at 26.6°±1°C, but humidity was controlled. If the newly emerged adults were be used as releases, they were held in the labora- 6-8 days to allow ample time for mating and position so adults would be provided for the suc- ing generation.

A test was made to determine whether a higher ntage parasitism could be obtained by leaving weevil eggs exposed to the parasites longer than day. Seven vials, each containing 50 unsexed ites were stocked with fresh weevil eggs. Samples gs were removed daily for 7 days. The results Table 1) showed that nearly all parasitism occurred ng the 1st day. No appreciable increase in sitism occurred when eggs were left longer than ay. Although mortality of adult parasites was not ded during the test period, survival was excel- only a few were dead at the conclusion of 7 s.

RESULTS AND DISCUSSION.—*T. haitiensis* successfully asitized eggs of *D. abbreviatus*, *P. litus*, and *P.* ata. Eggs of *A. floridanus* were stung, but no elopment of parasites occurred in these eggs. dult parasites generally emerged from the hosts' eggs 6-18 days after stinging, but on several occasions, ayed emergence was recorded. An extreme case urred in eggs parasitized Nov. 3, 1969: 2 adult asites emerged June 4, 1970 (213 days later). he reasons for this delay are unknown.

Over 86,000 adult *T. haitiensis* were reared and re- ased during a 4-month period (July 10–Nov. 14, 969). Generally, releases were made in groves known to be infested with *D. abbreviatus*, but since egulatory agencies were regularly using chemical eatments of carbaryl to control adult weevils, we selected other release sites also outside the regulated area. These sites were known to have infestations of *Pachnaeus* spp. One weevil egg mass from a citrus grove heavily infested with *D. abbreviatus* at Apopka was collected by A. G. Selhime Dec. 9, 1969. Two adult parasites, identified by B. D. Burks as *T. haitiensis*, were reared from this egg mass.

Table 1.—*T. haitiensis* reared from eggs of *D. abbreviatus* exposed to adult parasites for 1–7 days (50 parasites/replicate; 7 replications).

No. host's eggs	Days exposed	No. parasites emerged	% parasitization
5099	1	1894	37.1
5795	2	2518	43.5
5115	3	1593	31.1
8001	4	3702	46.3
7374	5	4245	57.6
6524	6	3461	53.1
7478	7	2631	35.2

Establishment of *T. haitiensis* is not proved at this time, although we have 1 example of successful parasitization in the field. Evaluation of the parasite as a biological control agent for root weevils feeding on citrus in Florida will be made after we have proof that the parasite has been established.

REFERENCES CITED

Wolcott, G. N. 1948. The insects of Puerto Rico: Coleoptera. J. Agr. Univ. Puerto Rico 32 (2): 225–416.

Woodruff, R. E. 1964. A Puerto Rican weevil new to the United States (Coleoptera: Curculionidae). Fla. Dep. Agr., Div. Plant Ind., Entomol. Circ. 30: 1–2.

1968. The present status of a West Indian weevil (*Diaprepes abbreviata* (L.)) in Florida (Coleoptera: Curculionidae). Ibid. 77: 1–4.

Toxicity of Malathion to Gamma-Irradiated and Nonirradiated Adult Red Flour Beetles[1,2,3,4]

ROBERT R. COGBURN and ROY D. SPEIRS[5]

Stored-Product Insects Research Branch, Market Quality Research Division, Agr. Res. Serv., USDA, Savannah, Georgia 31403

ABSTRACT

Tests were conducted to determine the effect of combining treatments of malathion and gamma radiation applied to adult *Tribolium castaneum* (Herbst). Radiation was applied before the chemical treatment. The dosage of 5 krad did not produce any mortality when applied alone and actually afforded some protection to the insects against the malathion. At dosages of 10 krad or more, however, radiation combined with malathion at the rate 0.05 μg/insect was slightly more lethal than either malathion or radiation alone. Combination treatments produced earlier mortalities than did radiation alone.

Much of the available literature regarding the lethal and sterilizing effects of gamma radiation on stored-product insects was reviewed by Watters (1968). The possibility that irradiation may become an established technique for controlling stored-grain insects has been increased because of incomplete protection obtained with insecticides (Floyd 1961, La-Hue 1969), development of resistance to insecticides by stored-product insects (Lindgren and Vincent 1966), and the possibility of residues occurring on grain or fractions of the grain in excess of safe limits (McGaughey 1969).

If gamma radiation becomes a prevalent method

[1] Coleoptera: Tenebrionidae.
[2] Received for publication Dec. 9, 1970.
[3] This research was partially supported by U.S. Atomic Energy Commission Contract no. AT(49-11)-2676.
[4] Mention of a proprietary product does not imply endorsement by the USDA.
[5] Entomologist, Stored-Rice Insects Investigations, Beaumont, Tex., and Stored-Product Insects Research and Development Laboratory, Savannah, Ga., respectively. The assistance of Mrs. Ruby Hart, Biological Laboratory Technician at the Savannah Laboratory, is gratefully acknowledged.