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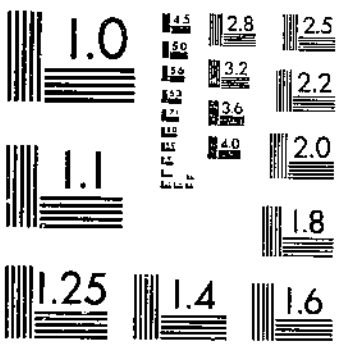

MICROCOPY RESOLUTION TEST CHART
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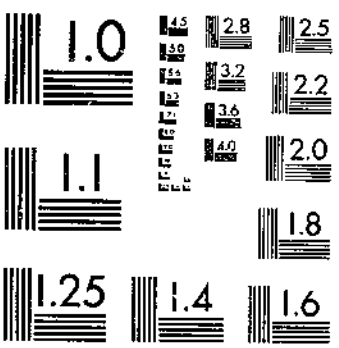

MICROCOPY RESOLUTION TEST CHART
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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

IMPORTED PARASITES OF THE EUROPEAN CORN BORER IN AMERICA

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CONTENTS

THE REASON FOR PARASITE INTRODUCTION

The status of an insect in its native habitat is the result of years of natural selection, the struggle against enemies and diseases, and the varying abundance or scarcity of its food. Many other factors, more numerous than can be fully realized, influence this struggle for survival that is waged by a given species; and one of the most wonderful things in the world is the interrelation which obtains among these many varying factors and the manner in which a single insect species reacts to each factor.

When an insect is carried to a new country it faces new conditions. Some of these tend to stimulate and others to retard its increase. In other words, the forces that operate in preserving the balance of nature begin to work. If in spite of its novel environment the insect increases rapidly enough to affect economic conditions adversely, the repressive factors which are apparently wanting must be sought by a study of its natural control in the countries where it has been present for centuries.

In most cases an important missing factor is found to be the beneficial parasites which live and propagate at the expense of their insect hosts. These must be imported and established, if possible, to augment the natural control of the introduced pest in its new environment.

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Percentage of parasitism of an insect pest in its native home, as compared with the parasitism of other insects by other parasites, may be no indication of the part the particular parasites are playing in the preservation of the normal balance. If a host insect is largely held in check in its native home in the absence of very high percentages of parasitism, and damage by it is slight and rare, the natural balance may be considered nearly perfect. In such cases, however, parasite importation is just as important, and may be more important than in cases where the parasitism is high, for the factors responsible for the excessive increase of the host in its new home may cause a corresponding increase in its parasites.

The objective in control by the use of parasites is to prevent the peaks of reproduction from rising beyond the normal and thus keep the host insect down to a point where it remains of little or no economic importance.

THE ORGANIZING OF THE CORN-BORER PARASITE PROJECT

The Bureau of Entomology undertook the European investigation of the corn borer, *Pyrausta nubilalis* Hbn., in the fall of 1919.[1] W. R. Thompson was put in charge of the work, and special emphasis was to be directed toward the careful study of, and the collection and shipment of, the most promising parasites.

A parasite department was also established under D. J. Caffrey, who was in charge of the bureau laboratory at Arlington, Mass. There the primary objects were the reception of the parasites and the securing of the development and liberation of the selected species. Both the home and foreign laboratories have increased their spheres of activity and scale of work. An increasing amount of parasite work, directed from Arlington, is being conducted at the corn-borer laboratories of the bureau at Silver Creek, N. Y., Sandusky, Ohio, and Monroe, Mich. Cooperation is fostered with Canadian workers under A. B. Baird, of Chatham, Ontario.

THE IMPORTANT INTRODUCED PARASITES[2]

Of the species of parasites encountered in European investigations, 10 have been considered of sufficient importance to justify their importation into and liberation in this country. They are the following: In the Tachinidae, *Masicera senilis* Rond.[3] and *Zenillia roseanae* B. & B.; in the Ichneumonidae, *Eulimneria crassifemur* Thom.,[3] *Dioctes punctoria* Roman,[3] *Exeristes roborator* Fab.,[3] and *Phaeogenes planifrons* Wesm.[3]; in the Braconidae, *Microbracon brevicornis* Wesm., *Microgaster tibialis* Nees,[3] *Apanteles thompsoni* Lyle,[3] and *Macrocentrus abdominalis* Fab.

The numbers liberated and recoveries are shown in Tables 1 to 7, pp. 24 to 27.

MASICERA SENILIS ROND.[4]

The tachinid fly *Masicera senilis* deposits living larvae on the food plant, close to a corn-borer tunnel or a point where the borer is feeding.

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[1] THOMPSON, W. R., and PARKER, H. L. THE EUROPEAN CORN BORER AND ITS CONTROLLING FACTORS IN EUROPE. U. S. Dept. Agr. Tech. Bul. 58, 62 p., illus. 1928.

[2] For more extended details, see THOMPSON, W. R., and PARKER, H. L. Op. cit.

[3] These species have been recovered after liberation in this country.

[4] THOMPSON, W. R. ON THE TAXONOMIC VALUE OF LARVAL CHARACTERS IN TACHINID PARASITES (DIPT.). Ent. Soc. Wash. Proc. 24: [85]-93, illus. 1922.

The parasite larva is capable of seeking its host for a short time, and, if successful, bores its way quickly through the skin. It lives inside the host larva until both are fully grown, killing the host usually in the last instar, after which it makes its way out and forms a chocolate-colored puparium, or pupal skin, from which the adult fly shortly emerges. The seasonal history is somewhat irregular. This species usually hibernates as a second-instar larva inside the corn borer.

ZENILLIA ROSEANAE B. & B.[1]

The tachinid *Zenillia roseanae* deposits living larvae as does *Masicera senilis* and is very similar in many other ways, although it is apparently more restricted in its range in Europe.

EULIMNERIA CRASSIFEMUR THOM.

Eulimneria crassifemur (fig. 1) deposits its eggs inside the hosts, and in the laboratory seems to prefer third-instar larvae, especially those feeding inside webs or corn tassels. The host is not killed until it reaches full larval growth. Then the parasite bores out and spins a tough cocoon in which it hibernates except in those environments which produce two generations of borers. The same factors produce two generations of Eulimneria. The time spent in summer cocoons is short, whereas nearly six months is spent within the cocoons of the hibernating generation. In Europe this species has a wide range.

DIOCTES PUNCTORIA ROMAN

Dioctes punctoria (fig. 2) is an ichneumonid which in most respects looks and acts very much as does Eulimneria, the most important exception being that the winter is spent as a first-instar larva while inside the borer. Its range in Europe is limited, and it is most effective in Italy.

EXERISTES ROBORATOR FAB.

Exeristes roborator (fig. 3), an ichneumonid segregate of the old Pimpla group, pierces the cornstalks with its long ovipositor, kills the host larva, and deposits its eggs on the body. The resulting larvae feed externally, and only one individual completes development on a host, although more may be present at the start. The larval feeding stage is necessarily short. This species has several generations a year and hibernates as a full-fed larva in the corn-borer tunnel, protected by a thin but tough cocoon. In Europe this species has a wide range but is seldom important. Breeding methods are explained later under the heading "Laboratory breeding methods."

PHAEOGENES PLANIFRONS WESM.

Phaeogenes planifrons (fig. 4) is apparently a true pupal parasite. The parasites search the tunnels that the borers make in the corn and apparently oviposit in the fresh chrysalids. Adults emerge shortly and live for long periods. They hibernate in the adult stage and apparently parasitize the next generation of chrysalids. In Europe the geographic range is wide, but as a corn-borer parasite it is most noticeable in Italy. It has been recovered in Massachusetts in satisfactory numbers.

[1] THOMPSON, W. R., and THOMPSON, M. C. STUDIES ON ZENILLIA ROSEANAE B. & B., A PARASITE OF THE EUROPEAN CORN BORER (PYRAUSTA NUBILALIS HB.). Ent. Soc. Wash. Proc. 23: 127-139, illus. 1921.

MICROBRACON BREVICORNIS WESM.

The braconid *Microbracon brevicornis* (fig. 5) attacks full-grown larvae. These are paralyzed, and from 10 to 40 eggs are deposited on each. The parasite larvae hatching from these eggs feed externally on the motionless borer. They complete their larval develop-

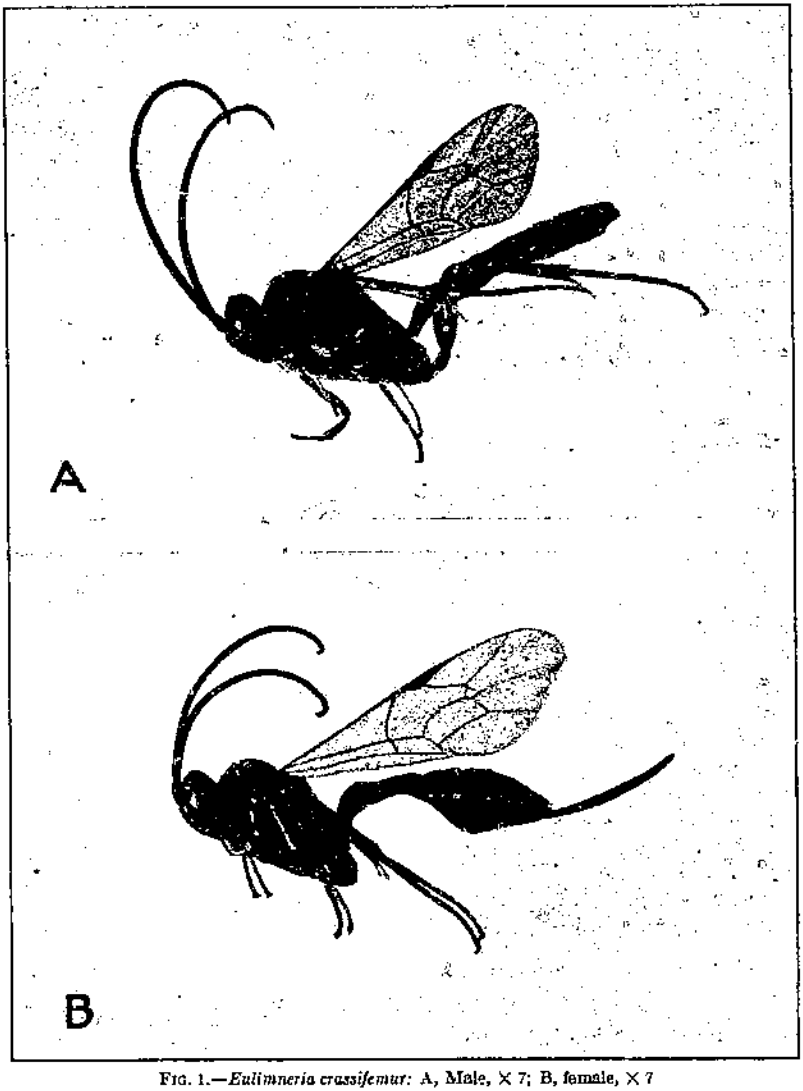

FIG. 1.—*Eulimneria crassifemur:* A, Male, × 7; B, female, × 7

ment in from three to four days and spin white cocoons from which adults emerge that are capable of reproducing or of hibernating in this adult stage if winter approaches. At other stages they are not capable of successful hibernation. This species is apparently widely distributed in Europe, but its value is questionable, except under certain circumstances where corn is stacked in large areas throughout

the winter. Apparently factors favorably influencing successful hibernation do not exist here. Breeding methods for Microbracon

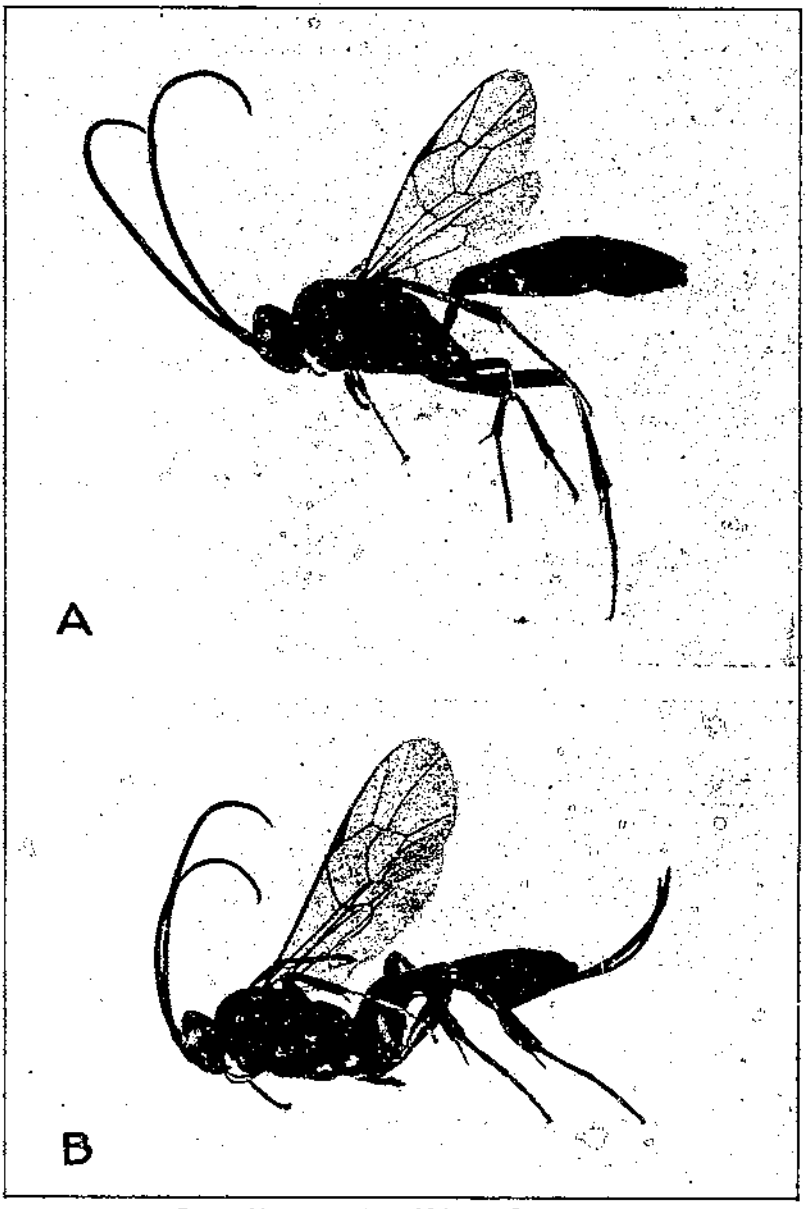

FIG. 2.—*Diodes punctoria:* A, Male, × 7; B, female, × 7

are explained and illustrated later, but continuance of work on this species seems undesirable unless more factors in its favor can be found.

MICROGASTER TIBIALIS NEES

Small borers, preferably those in the second instar, are selected for ovipositing by *Microgaster tibialis*. (Fig. 6.) These host larvae may be crawling free or in a feeding web. Although several eggs are sometimes deposited in the host, only one larva fully develops in a single borer. The parasite kills the host in the late fourth instar or the

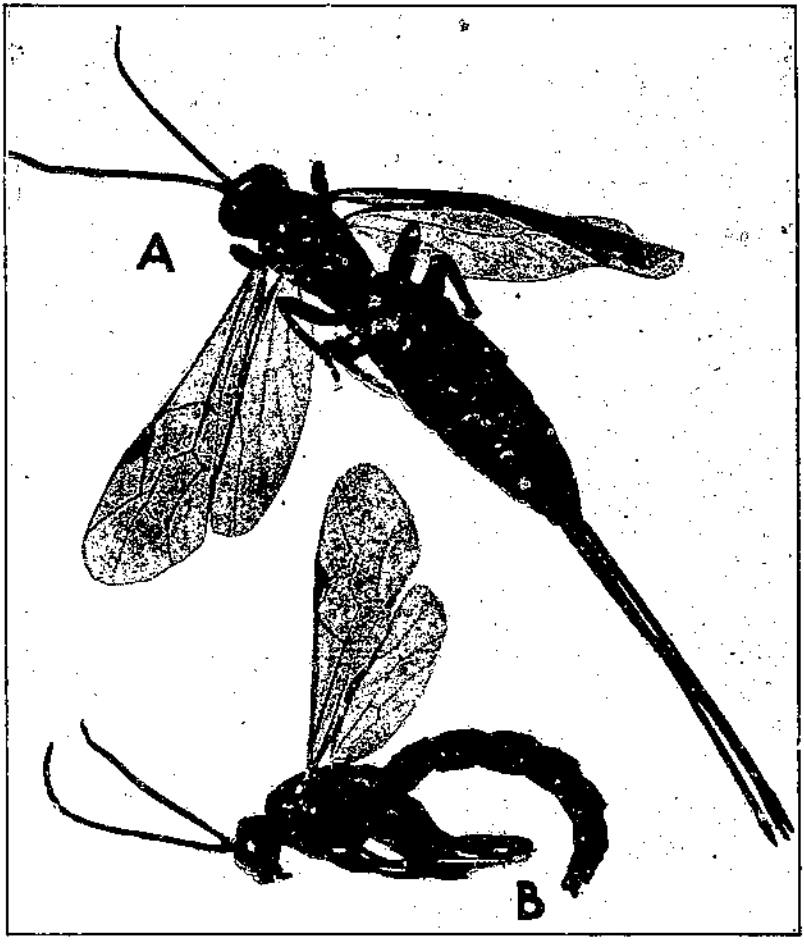

FIG. 3.—*Exeristes roborator:* A, Female, × 7; B, male, × 7

early fifth. This species, like several others, synchronizes its development with that of its host and has as many generations in a given area as the corn borer. It should prove very valuable in this country. It is especially valuable in northern France, but ranges south well into Italy. Breeding methods are well worked out at the Arlington, Mass., laboratory, as will be explained later.

APANTELES THOMPSONI LYLE

The life history of *Apanteles thompsoni* (fig. 7) is very different from those of the other parasites of the corn borer. It spends the

winter inside the living host, there being from 8 to 40 individuals of the second instar within a single borer. These parasites kill the borer in May and form their white cocoons. In this stage the species is very sensitive to moisture. All emerging adults are females, and

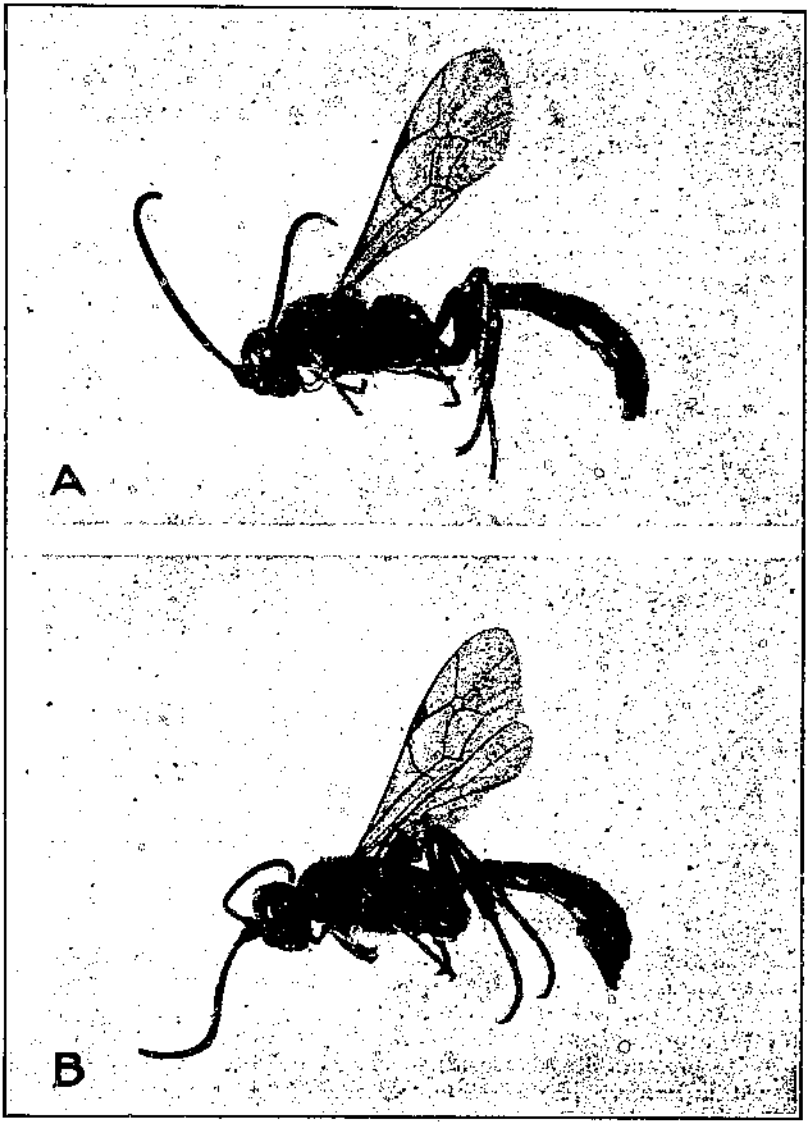

FIG. 4.—*Phaeogenes planifrons*: A, Male, × 7; B, female, × 7

these females reproduce freely, their progeny being always females. This statement is based on the emergence from field collections made during three years in Europe and on five complete generations bred in the Arlington laboratory.

One thrust of the ovipositor suffices for the deposition of as many as 40 eggs. Third-instar borers are apparently most satisfactory for

oviposition, but full-grown larvae or borers which have hibernated are also parasitized. In order to oviposit, this Apanteles often enters tunnels made by the borers. Its geographic range is presumably limited, but it is especially common in borers found in weeds in northern France. This species is being bred at the Arlington laboratory, and its liberation in the more western States will be watched with great interest.

MACROCENTRUS ABDOMINALIS FAB.

The braconid *Macrocentrus abdominalis* (fig. 8) also produces many parasites per host. The winter is passed as a minute egg inside a hiberating borer, and the resulting larva is ready by May to form its cocoon. The adults mate readily, and in the laboratory the females are found to prefer the small larvae under the feeding webs. Only one generation has been obtained under laboratory conditions, and there is much to be learned regarding this species.

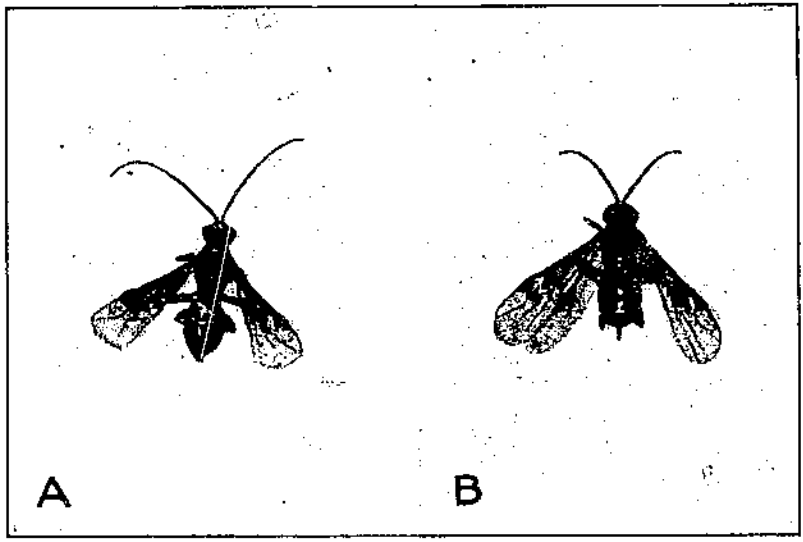

FIG. 5.—*Microbracon brevicornis*: A, Male, × 7; B, female, × 7

OTHER SPECIES

In addition to these 10 species, several miscellaneous species of primary parasites have been reared from the corn borer in Europe and from those imported to this country for parasite work at the Arlington laboratory. None of these have occurred in any great numbers. They are presumably the result of occasional attacks by parasites of other stalk borers which have not developed to a point of specializing on *Pyrausta nubilalis*.

LABORATORY BREEDING METHODS

EXERISTES ROBORATOR

W. R. Thompson, in charge of the parasite laboratory at Hyères, France, solved certain fundamental problems in breeding *Exeristes roborator*. His technic was modified and improved to get better co-

ordination. Where Doctor Thompson had used lantern-globe cages, the writer and his associates gradually developed a compartment cage (fig. 9) with which the work could be conducted efficiently and speedily. Furthermore, this cage provided better living conditions for the parasites. Mating was satisfactorily brought about with this species.

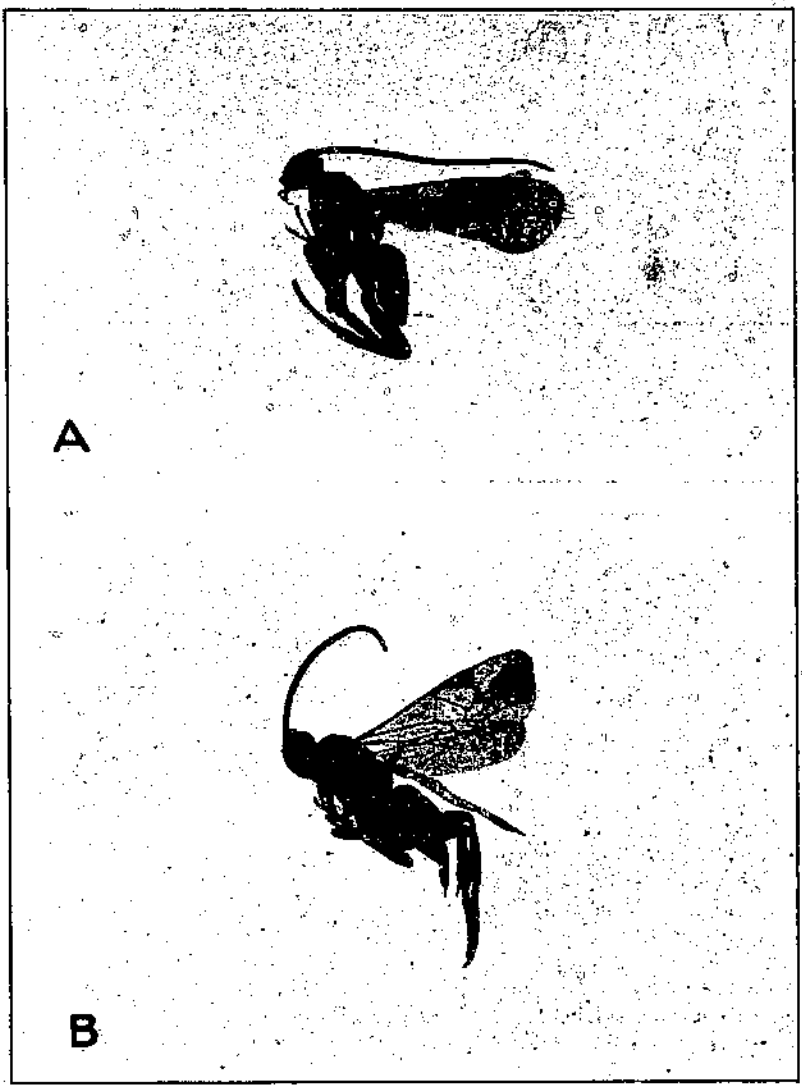

FIG. 6.—*Microgaster tibialis*: A, Male, × 7; B, female, × 7

In fact, the males could be, and were, removed after several days as superfluous. By placing host larvae and sugar water in the only light part of the cage, the attraction of the light was utilized, and a place for oviposition and feeding was constantly at hand. The back of the cage was made of removable strips. This afforded an opportun-

ity for cleaning and handling material in three compartments at the same time, phototropism meanwhile holding the adults in the front of the compartments. In each section were two pieces of cotton wet with sugar water and a supplementary food supply of freshly killed borers pinned to a piece of corn pith.

In nature *E. roborator* locates the borer, pierces the plant with her ovipositor, and after stinging the borer to death lays her eggs on it. Following Doctor Thompson's method of imitating natural conditions, sections of corn pith are hollowed out and a number of freshly killed borers put into this artificial tunnel. The tunnel, or groove, is then covered by a wrapping of wheat-straw paper fastened with small rubber bands. When "loaded," this section of pith is placed in the lightest part of the cage. The next day it is removed and a fresh one substituted.

The young of *Exeristes roborator* are cannibalistic, and only one parasite completes development on a single host. The pith sections are, therefore, opened (fig. 10), and all the eggs are removed (a camel's-hair brush being used for this purpose) and placed temporarily on a glass plate. (Fig. 11.) As many corn-borer larvae as there are parasite eggs immediately available are then killed by means of hot water. Countless experiments have been conducted which show that the hot-water method is preferable to other methods. Subsequent experiments showed that the exact temperature and time of immersion required to obtain the best results was 52.5° C. for two and one-half minutes. This is a delicate and critical operation, as the previous storage condition and development of borers used may cause variation in the degree of temperature necessary to get proper killing. The killing point must be barely passed, since immersion beyond the exact time coagulates the body contents.

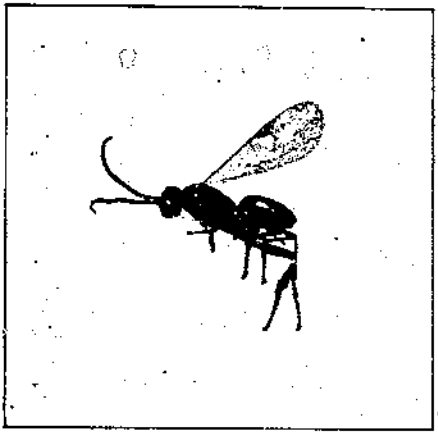

FIG. 7.—*Apanteles thompsoni*, female, × 7

The dead borers, with one egg placed on each one, are then put into small individual shell vials. Racks have been developed for holding these vials in a tray at an angle of 45°. (Fig. 12.) These racks are put into the trays with the vial openings of each row facing those of the row adjacent, and cotton strips are placed between the rows of vials. The weight of the tray next above forces the cotton tightly against the vial openings, thus making unnecessary the use of individual cotton plugs. The parasite egg hatches in about 24 hours, and the resulting larva feeds on the dead borer. A moist, warm atmosphere is best for its development. A second borer sometimes must be furnished, but usually this is not necessary if temperature and time of immersion have been accurately gauged.

When it has finished feeding the young parasite spins a rough cocoon attached to the glass vial (fig. 13), and it is then set aside for hibernation, future breeding, or liberation. When the parasites are

intended for hibernation the vials are packed in small cardboard boxes and kept at a temperature below 40° F. and at approximately 95 per cent humidity until it is desired to use the parasites for breeding or liberation.

When it is intended to liberate the emerging parasites these boxes are placed in an emergence cage, darkened except for a detachable section which is light. The emerging adults come to this light section and find themselves in a large well-ventilated compartment where they may move freely and mate. Two of these light compartments are available, and each day one is removed and the empty one put in its place. If this section is properly placed, phototropism holds the parasites in it until a cover can be put in place. A further opportunity to mate is given, and this detached section is taken to the field, where the cover is taken off (fig. 14) and the parasites are

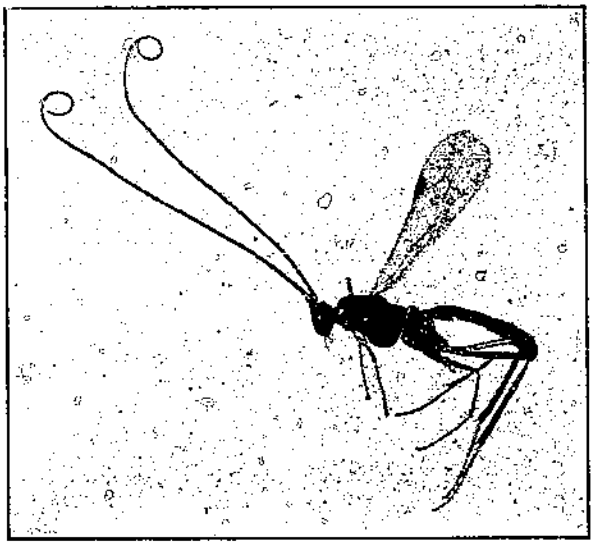

FIG. 8.—*Macrocentrus abdominalis*, male, × 7

allowed to escape. Careful estimates are made of the number of adults liberated each day. An accurate emergence count is possible by this method only at the end of the emergence period by examination of the total number of vials used in the cage. This accurate total figure, when checked against the daily estimates and prorated, gives approximately the number for each liberation point. Any slight inaccuracies are preferable to the risk of having the adults injured or improperly mated for the sake of the more accurate counts which would be possible by other emergence methods.

The matter of washing shell vials was a problem in itself. The method finally adopted was to pack them in wire racks (fig. 15), boil them in a solution of lye, rinse with a hose, boil again in the best laundry-soap solution, and rinse thoroughly in hot, clear water.

Both Exeristes and Microbracon parasitize full-fed host larvae. Fortunately these host larvae could be collected at a period when they no longer required food, and methods could be worked out for

building up a reserve supply. They are placed in wire-screen cages between folds of newspaper and stored in a moist, cold atmosphere.

MICROBRACON BREVICORNIS

Microbracon brevicornis, or *Habrobracon brevicornis*, as it was formerly called, presented a comparatively simple problem for small-

FIG. 9.—Compartment cage for Exeristes, viewed through the glass front. Stalks (1) contain borers, $\times \frac{2}{3}$

scale breeding. Paul Genieys [6] under Doctor Thompson at Hyères, France, worked out the details of its life history very carefully. Methods enabling large-scale production of this particular parasite were developed in 1921 and in the early spring of 1922, at Arlington, Mass.

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[6] GENIEYS, P. HABROBRACON BREVICORNIS WESM. Ann. Ent. Soc. Amer. 18: 193-202, illus. 1925.

Mating was a critical point in the breeding work. Unmated females of Microbracon deposited eggs, but the resulting offspring were always males. Seven types of cages for mating the sexes were tried under identical conditions. Female progeny from the three best types of cages (fig. 16) averaged about 2 per cent in 21 by 17 by 5 inch cages, 7 per cent in 4 by 1 inch glass vials, and 13 per cent in smaller homeopathic vials. The experiment with the homeopathic vials was continued (fig. 17), and it was found that by apportioning 5 females and 10 males to each vial the percentage of female progeny was raised to 17. Temperature change alone raised the rate from 17 per cent at 60° to 70° F. to about 40 per cent at a constant temperature of 85° F. Keeping the sexes separate for 24 hours before mating resulted in a still higher percentage of female offspring.

FIG. 16.—Corn-pith sections with the paper removed, showing dead borers and the eggs of *Exeristes roborator*. Natural size

While the mating problem was being studied, many reactions, habits, and peculiarities of the parasite under different conditions were noted. Adult females stung the host larvae until the latter became motionless and then fed repeatedly at the puncture holes. Artificial food prolonged somewhat the life of the parasites, but when a frequent, regular supply of host larvae was furnished the blood of these alone was sufficient for the females. Artificial food was necessary to prolong the life of the males for more than four or five days, but with suitable mating methods results were obtained before the expiration of this period, so that finally no artificial food had to be given to either sex.

Homeopathic vials proved difficult to keep clean, and parasites were often injured in removing the cotton plugs, as too much silk was spun by the host larvae near the plug, and several other disadvantages existed. Other small containers were experimented with. Glass-topped stender dishes (fig. 18) were found ideal in every way and were handled more than four times as quickly as the homeopathic vials. The vials are still used to bring about mating, but stender dishes have supplanted them for actual oviposition.

Experiments were conducted to determine the proper number of parasites and host larvae for each stender dish and the time necessary for a suitable average egg deposition. Forty eggs or more per host produced nothing, or at best but undernourished progeny. On the other hand, an insufficient number of eggs used up the supply of host larvae too fast. An average of 20 eggs per host produced good results, and three Microbracons and two corn borers per stender dish gave a suitable average over 24-hour periods.

Host larvae on which eggs have been deposited (fig. 19) never move again. Advantage of this fact was taken to remove them to a glass plate or cardboard, and no detriment to the parasite larvae resulted. The female Microbracons, therefore, could be left constantly in the stender dish and two fresh borers substituted each morning when the parasitized ones had been removed. A fairly moist, warm atmosphere during the larval period gave the best results. As soon as the short feeding period was finished the parasite larvae attached their cocoons firmly to the glass or cardboard. (Fig. 20.) When the larvae had thus packed themselves in their silken cocoons attached to the cardboard, the whole strip was immediately shipped. Upon arrival at their destination they were usually still in the cocoons and in good condition, but ready to emerge for mating and liberation.

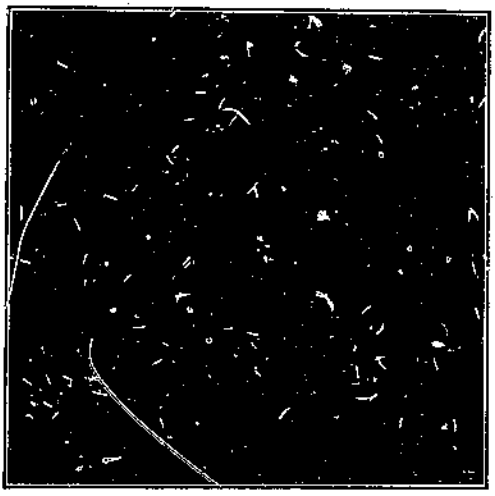


FIG. 11.—Eggs of Exeristes on a glass plate. Natural size.

The sexes are easily separated for mating by allowing adults to escape from the emergence cage into a shallow open cage with its glass back toward the light. (Fig. 21.) Phototropism holds the adults in the shallow cage, and the light background enables one to distinguish the ovipositor of the female and to note differences in the antennae of the sexes. When touched with a camel's-hair brush the adults drop or fly downward and are caught in homeopathic vials for mating, as previously explained.

PRESENT STATE OF THE WORK WITH EXERISTES AND MICROBRACON

There has been but little change since 1923 in the methods developed at the Arlington, Mass., laboratory for breeding the two parasites just treated. After 28,991 Exeristes and 1,054,400 Microbracon had been liberated, breeding stock and instructions were furnished to A. B. Baird, of the Dominion Corn Borer Laboratory, at Chatham, Ontario, the Microbracon in 1923 and the Exeristes in 1924.

In the following three years Mr. Baird bred and liberated approximately 120,000 Exeristes and 2,500,000 of Microbracon for the

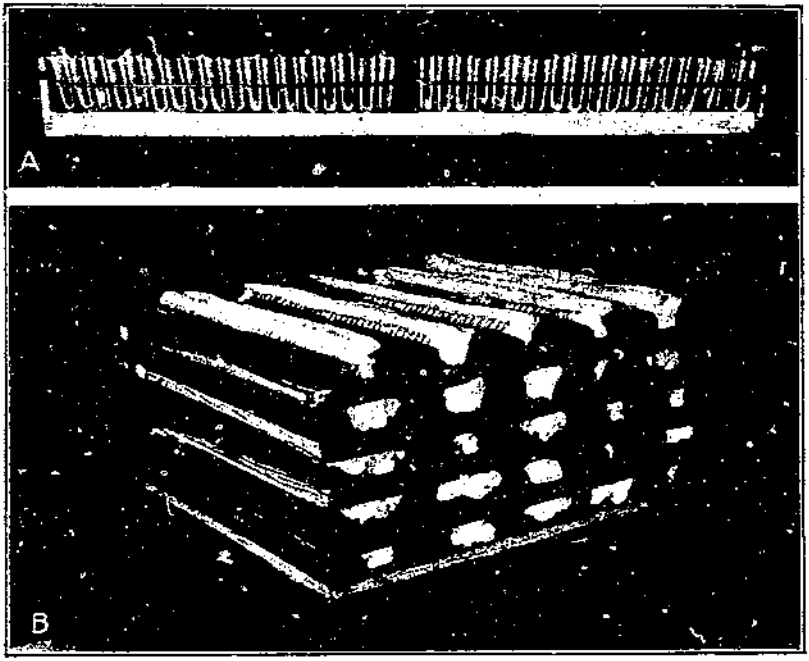


FIG. 12.—Trays and racks holding vials containing Exeristes larvae. A single rack holding the parasitized corn-borer larvae is shown at A

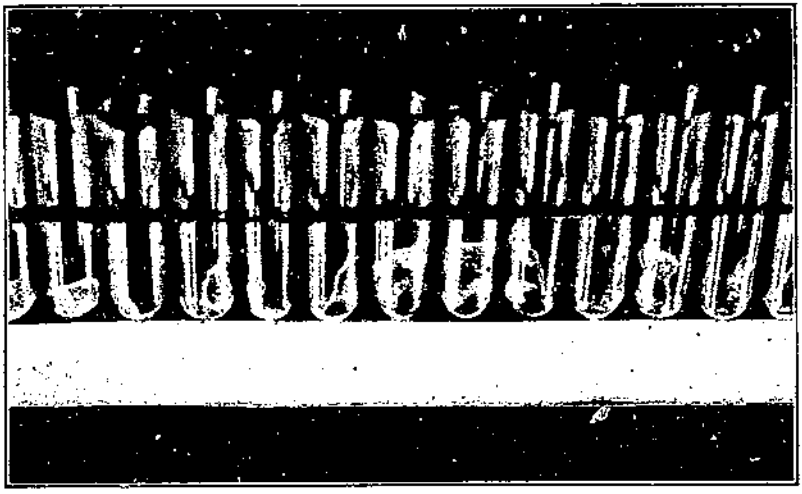


FIG. 13.—Cocoons of *Exeristes roborator* in shell vials. About natural size

control of an infestation of the corn borer, giving them an excellent test in an area in which it has but one generation per year.[7]

No work has been done at Arlington with the Exeristes since the spring of 1926, but both species are being bred at the laboratory at Monroe, Mich., in the one-generation area; and further work will be carried on only for liberations under new conditions of climate or agricultural practice unless more favorable factors appear.

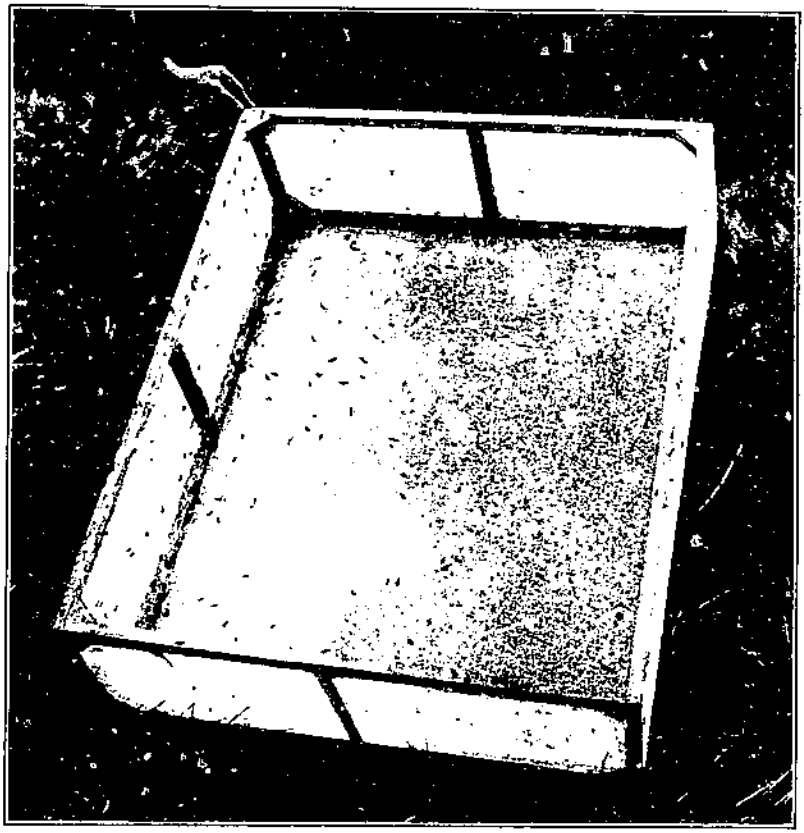


FIG. 14.—Liberation cage, a detachable section of emergence cage with the cover removed to allow the Exeristes parasites to escape. This method is also employed in the handling of other parasites

MICROGASTER TIBIALIS

Microgaster tibialis, as has been explained, deposits eggs inside corn-borer larvae of the second instar, but the host continues to feed normally until the parasite larva gradually weakens it. Death does not, as a rule, ensue until about two weeks after the egg is deposited, although colder weather, which retards the host, also retards the development of the parasite. Large-scale breeding operations entail not only the problems furnished by the parasite but also the difficult matter of providing satisfactory host larvae.

In order to secure host larvae for parasitism by Microgaster, Apanteles, and certain other parasites requiring immature borers,

[7] GIBSON, A. INTERNATIONAL ENTOMOLOGY—RETROSPECTIVE AND PROSPECTIVE. Jour. Econ. Ent. 20:37. 1927.

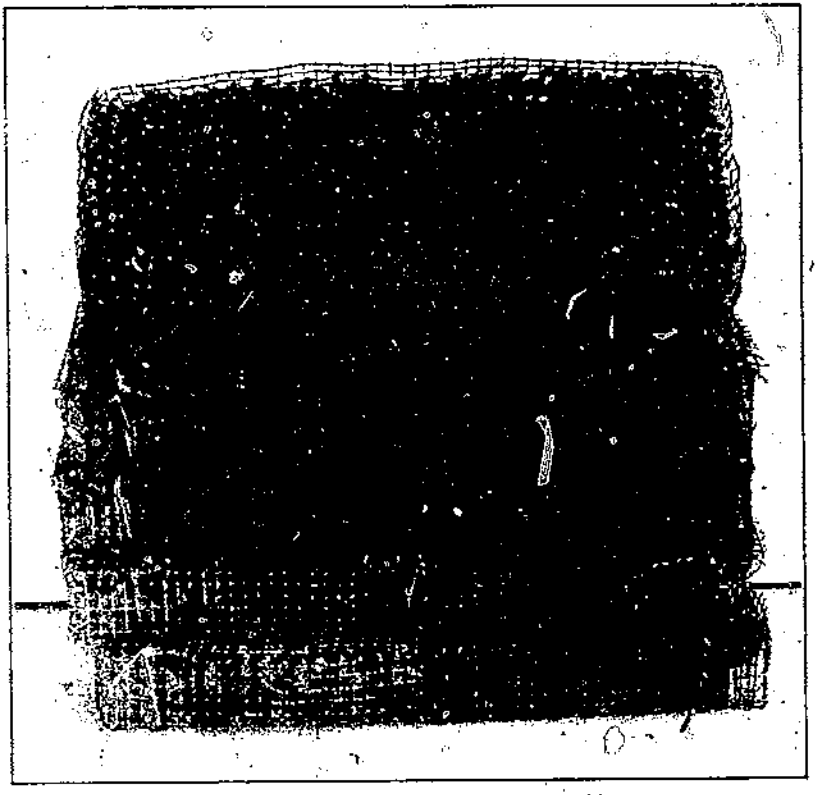


FIG. 15.—Shell vials packed in wire trays for washing

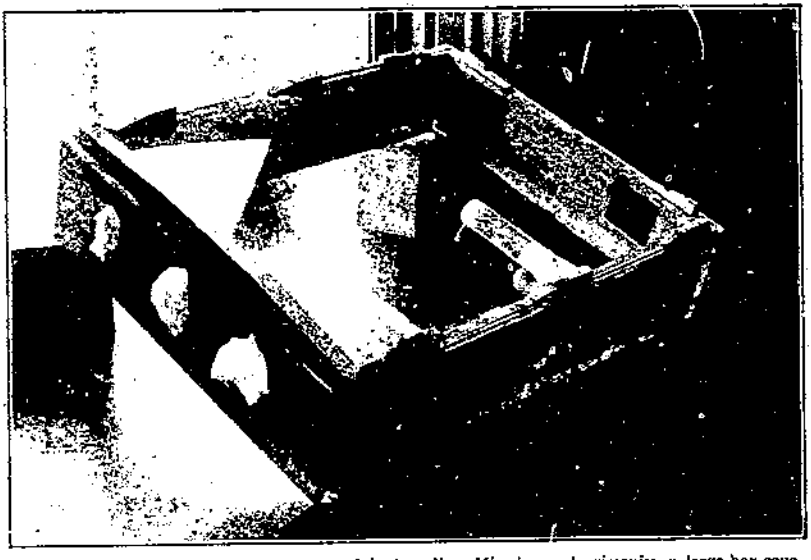


FIG. 16.—Three types of mating cages used in breeding *Microbracon brevicornis*: a large box cage, and two shell-vial cages resting on the glass cover of the large cage. The best results were obtained in the smaller vial

adult moths are put in a cage lined with screen as shown in Figure 22, with wet cotton kept on the bottom for necessary moisture. The cage has a small hinged door for introducing the moths, and three narrow slits cut in the top of the cage. Sheets of waxed paper are inserted in these narrow openings. The moths deposit egg masses freely on the waxed paper, but not on the screen or wet cotton.

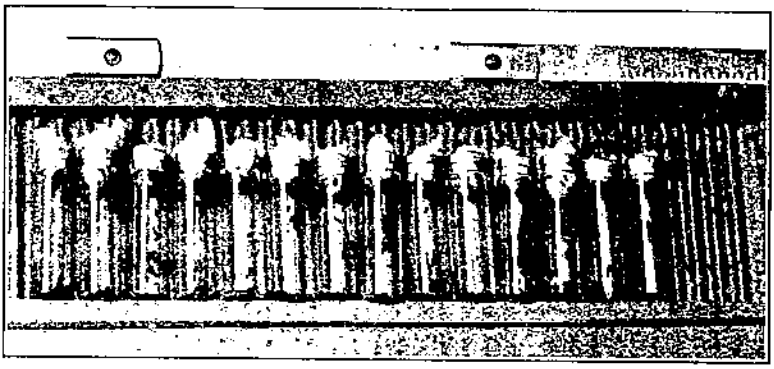


FIG. 17.—*Microbracon brevicornis* mating in small vials

The papers are removed each morning with eggs on them, and kept warm, in a very moist chamber. The eggs are ready to hatch in three days, and the papers are cut into pieces having approximately a certain number of eggs. The best method so far discovered is to place about 60 eggs in a 2-inch homeopathic vial closed with a cotton plug, a third of a string bean being inclosed as food for the resulting

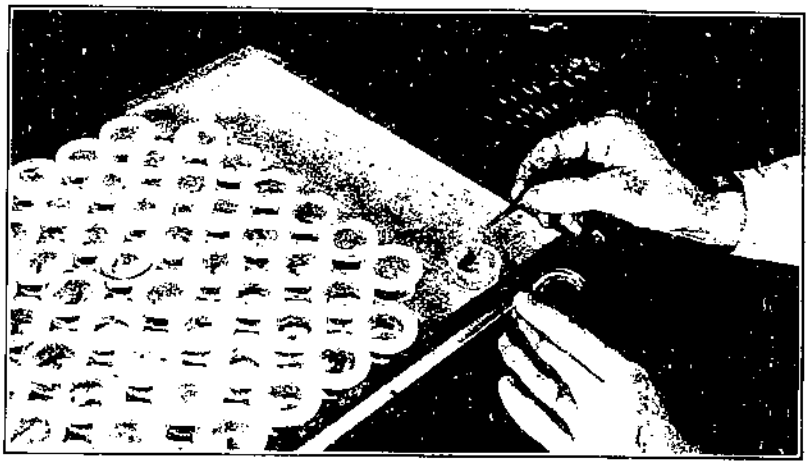


FIG. 18.—Stender dishes used for inducing rapid oviposition of *Microbracon brevicornis*

larvae. By the time the food should be renewed the larvae have reached the second instar and are ready for parasitism by Microgaster and certain other parasites. Most of them are ready to leave the food and migrate of their own accord at this time. The cotton plugs are removed and the vials so placed that the larvae migrate toward the light and into a glass-backed cage, indicated as A in Figure 23,

from which they can be easily removed for oviposition in the cage marked "B." Other methods are being experimented with which probably will produce healthy larvae with less trouble.

It was very difficult to induce mating with *Microgaster tibialis*, and since, without fertilization, males only are produced, this was very important. A certain small percentage of females mated under varied methods of handling, but uniform success at unseasonable times was not obtained until the sexes were separated and then allowed to come together in a large cheese-cloth cage, at a temperature of 64° F. Other things being equal, they mated far more readily at this temperature than at temperatures 2 degrees higher or lower.

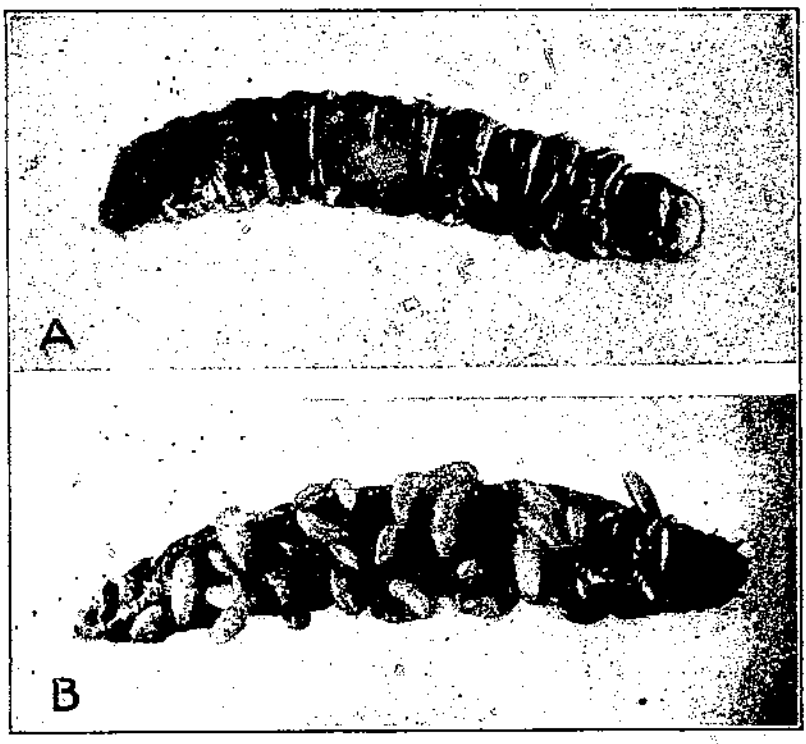
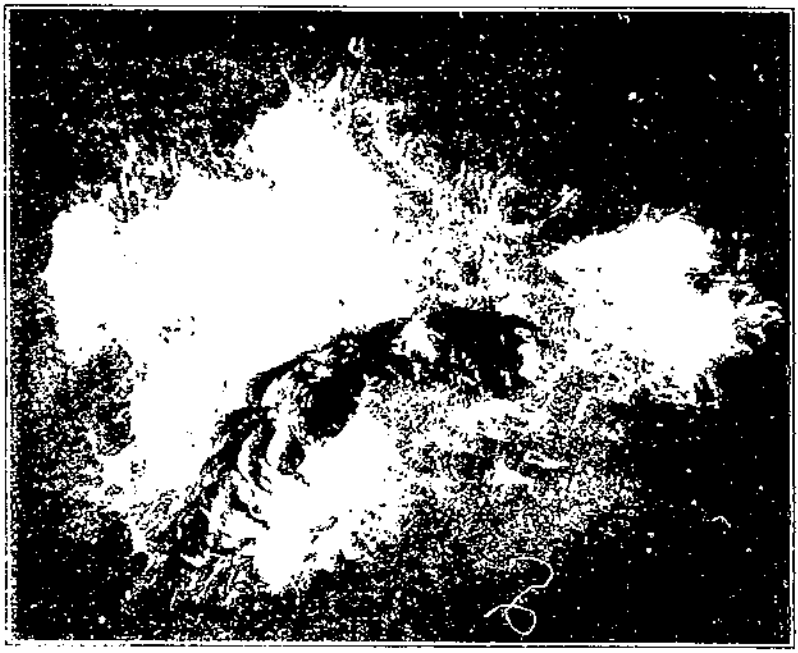
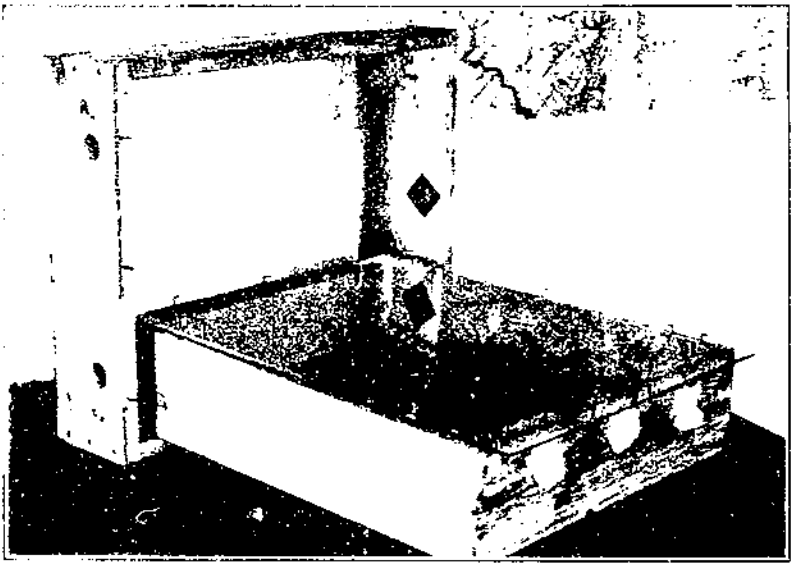


FIG. 10.—*Microbracon brevicornis:* A, Eggs on paralyzed corn borer; B, larvae feeding on a borer, ×5

Ninety per cent of the individuals often mate within a few minutes. The mated females are then caught in vials for breeding work. The unmated adults are separated and the sexes kept apart until the next day. Practically all the females mate within three days under these conditions.

Mated females are kept in small cages with wooden sides, glass fronts, and removable screen backs. The bottom of each cage is coated inside with black enamel. From 10 to 15 females are kept in each cage with loaf sugar for food and a piece of cotton wet with water for moisture. Except during short periods when the inmates are feeding or ovipositing, the cages are kept in a dark and cool closet. For inducing oviposition a cage is set on a small bench, as shown in Figure 23, B, with host larvae at the upper right (A);





underneath, fresh vials containing cut string beans at C and a supply of screen covers; and a tray for vials of isolated parasitized borers at the lower right (D). Parasitism is secured rapidly by placing small larvae in the oviposition cage and removing them as soon as an egg is deposited. The smoothly enameled bottom of the cage facilitates picking up the borers.

The object sought by this method of handling the parasites, which was adopted after countless unsatisfactory attempts at obtaining bulk oviposition, is to make every possible host larva and every parasite egg count. Cannibalism occurs among borer larvae; hence they are isolated in small glass vials, with copper screen tops, and with a section of string bean, changed after five days, to serve as food. These vials are handled in trays designed for convenience and

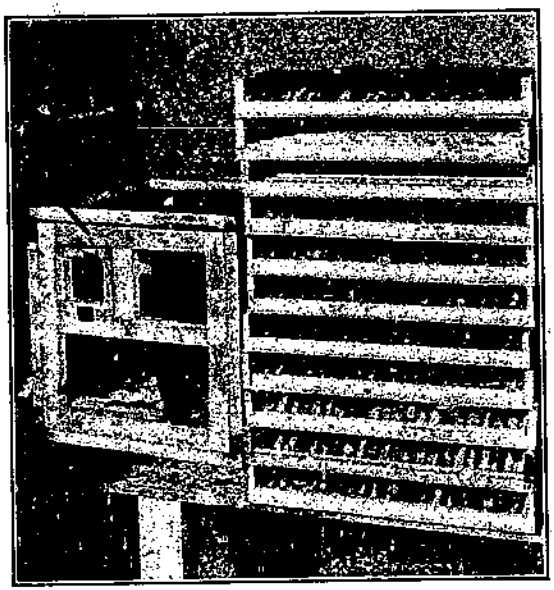


FIG. 22.—Cage designed for obtaining corn-borer eggs. At right, vials containing pieces of waxed paper on which eggs have been laid

to save time in subsequent examination, storage, and change of food, and are placed in an incubator closet. (Fig. 24.)

APANTELES THOMPSONI

Cocoons of *Apanteles thompsoni* must be kept with a constant, but limited, supply of moisture, otherwise few if any adults issue. Those kept in a vial with a string bean, which constantly gives off a small quantity of moisture, issued far better than those placed with or on various media artifically moistened. All adult Apanteles of this species thus far secured are females and are very delicate. They are fed and then placed immediately in a cool dark closet. Each day they are brought out to ordinary room conditions, fed, allowed to oviposit once in a corn borer—from 8 to 40 eggs are inserted—and returned to the closet. In this way they are kept alive for three or four weeks. Host larvae used for this species are

third instar, or larger, and are afterwards handled as are those parasitized by Microgaster.

IMPORTATION, LIBERATION, AND RECOVERY OF THE PARASITES

Tables 1 to 7 show what has been done along the lines of importation, liberation, and recovery of parasites of the European corn borer. Special stress has been laid and will continue to be laid on liberations

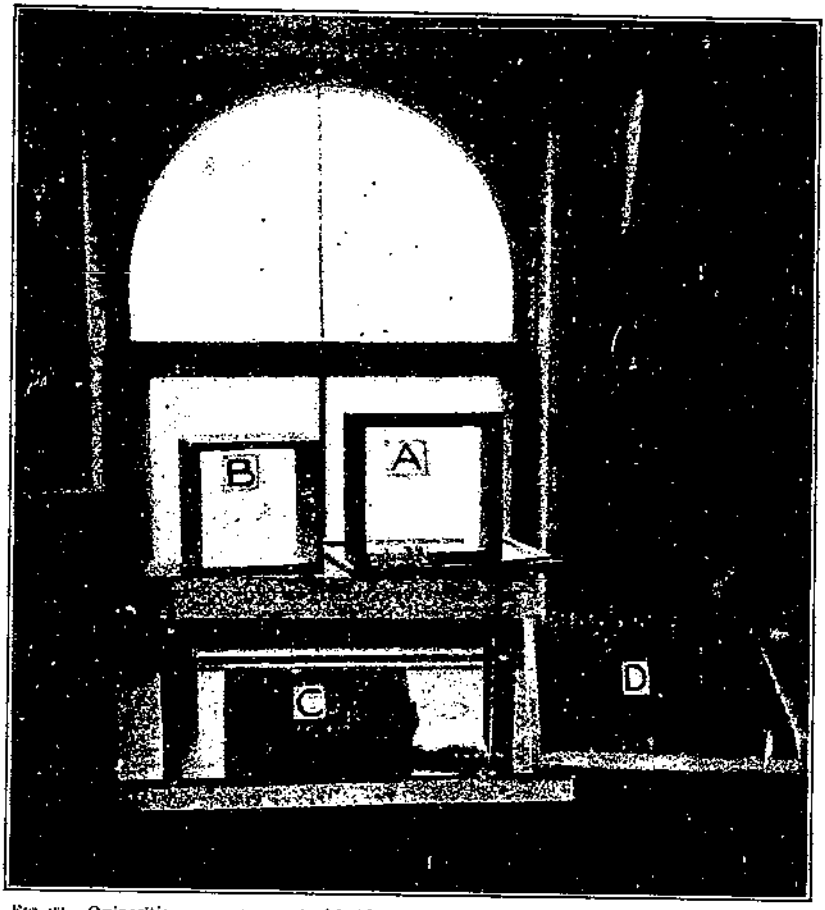


FIG. 23.—Oviposition apparatus used with *Microgaster tibialis*: A, Larval supply cage; B, oviposition cage; C, vials containing string beans; D, isolated parasitized borers

of parasites in the middle-western area. Many factors are present, which are not apparent without very careful study, which influence the selection and placing of the different species. Microgaster and Eulimneria, which have a wide geographic range in Europe and which should do well in the Middle West, pass the winter in their cocoons and are imported in this stage. The greater portion so received are forwarded to middle-western stations with cage plans and instructions for rearing the adult parasites and mating and liberating them.

The great importance of killing all hyperparasites which may be present in this field-collected material is explained very carefully

and is strongly urged. During the winters of 1926–27 and 1927–28, 250,700 Microgaster and 60,000 Eulimneria were sent out under this plan. The remaining cocoons were retained at Arlington for a more careful study of the hyperparasites, to furnish adults for breeding work, and so the excess adults could be liberated in an area that had already proven favorable for their reproduction in the field.

Apanteles thompsoni should be liberated at every liberation point shown in the following tables, from material bred in the laboratory

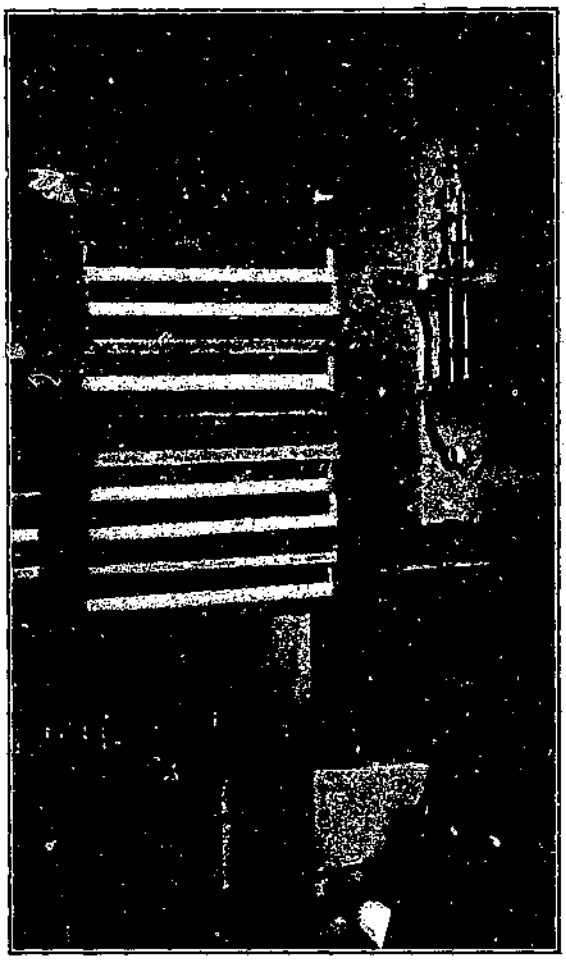


FIG. 24.—Corner of incubator closet for corn-borer parasites

at Arlington. Small liberations should prove valuable with this species, as only females are produced. Certain other species do not ship satisfactorily except when contained in living borers. This difficulty prevents, at present, extensive liberations outside of the New England infestation. Efforts will be made to devise methods for handling these species. Certain species apparently are not fitted for the climatic conditions existing in areas where the borer has only one generation, but it is proposed to try even these in limited tests in the western infestation.

TABLE 1.—*Importations of European corn-borer parasites from Italy and France* [1]

Year ended June 30—	Number of individuals of—										
	Corn-borer larvae	Zenillia	Masicera	Eulimneria	Dioctes	Microbracon	Exeristes	Microgaster	Phaeogenes	Apanteles	Macrocentrus
1920	20,267	120	88	80							
1921	76,258	784	290	7,620	10						
1922	76,645	63	87	350	450	1,300					
1923				1,000	168		1,001	100			
1924	8,105			583				2,160			
1925	154,408	689	186	2,637	2,043			9,226	1,601		
1926	502,600	3,865	2,277	14,615	2,157		350	34,741	5,440	5,935	3,885
1927	1,500,000	9,840	8,012	31,000	11,401			140,000	17,017	27,000	2,080
Total	2,338,223	15,361	10,940	57,865	16,220	1,300	1,411	186,227	24,058	32,935	5,965

[1] Doctor Thompson's figures on importations are used. Some of the figures are necessarily estimates based on dissection of borer larvae in France. Totals of host larvae, Eulimneria, Exeristes, and Microgaster, are actual counts. Table 2 gives the more valuable information as to the number of these received here in condition to produce adult parasites. The figures for the year ended June 30, 1928, will approximate those for 1927.

TABLE 2.—*Total liberation of European corn-borer parasites, by years* [1]

[Recoveries indicated by asterisk]

Year	Number of individuals of—									
	Zenillia	Masicera	Eulimneria	Dioctes	Microbracon	Exeristes	Microgaster	Phaeogenes	Apanteles	Macrocentrus
1920	90		31							
1921	784	360	4,068	10	400					
1922				168	1,054,600	56				
1923			733			*28,035				
1924			128	555	59,550	*10,728	1,640	1,460		
1925	650	186	2,221	1,201	163,870	*22,367	*0,856	2,319	3,477	
1926	3,254	3,031	*3,557	*5,705	63,264	*48,407	*21,387	*5,904	3,374	2,191
1927	42,891	*10,935	*26,589	*1,104	241,011	*50,313	*111,876	*0,917	*35,263	21,364
Total	47,778	14,452	38,227	8,834	1,573,095	169,806	141,768	19,680	42,114	23,555

[1] The figures for 1928 promise to be approximately as large as those for 1927.

TABLE 3.—*Liberations of European corn-borer parasites, by States*

[Recoveries indicated by asterisk]

State	Number of individuals of—										
	Zenillia	Masicera	Eulimneria	Dioctes	Microbracon	Exeristes	Microgaster	Phaeogenes	Apanteles	Macrocentrus	Total
Massachusetts	43,858	*13,309	*12,842	*8,167	1,082,270	*54,957	*55,538	*14,307	*34,288	20,453	1,340,010
New York					84,863	*12,089	995		1,201		100,078
Pennsylvania					18,230	6,433					24,663
Ohio	615	825	11,112	460	216,007	*46,488	*41,191	1,994	1,070	2,053	322,724
Michigan	3,278	318	*7,554	207	155,112	*43,407	16,617	3,379	3,625		233,497
Indiana					12,948	5,170					18,118
Illinois					3,635	362					3,997
Canada			[1] 6,719				[1] *27,427		[1] 1,021	[1] 1,049	36,216
Total	47,778	14,452	38,227	8,834	1,573,095	169,806	141,768	19,680	42,114	23,555	2,079,309

[1] Actual liberations from foreign material sent from Arlington. Canadian liberations from material bred at Chatham, Ontario, are not shown.

TABLE 4.—*European corn-borer parasites liberated in Ohio, by town, year, and species*

[Recoveries indicated by asterisk]

MICROBRACON

Year	Number of individuals liberated in—							
	Bono	Sandusky	Willoughby and Mentor	Ashtabula	Elyria	Oakharbor	Toledo	Total
1924		25,550						25,550
1925	30,000	90,000						120,000
1926	740	1,826	461					3,027
1927	10,030	15,000	20,000	10,200		7,200	5,000	67,430
Total	40,770	132,376	20,461	10,200		7,200	5,000	216,007

EXERISTES

1924	2,888	1,375	1,462					5,725
1925	*2,235	689	2,150					5,074
1926	*7,545	*9,670	4,085					21,300
1927	*3,482	*2,000	1,908	1,919	1,609	1,726	1,745	14,389
Total	16,150	13,734	9,605	1,919	1,609	1,726	1,745	46,488

MICROGASTER

1925		1,296						1,296
1926	*4,505	*1,002	2,725					8,292
1927	11,447	10,303	9,853					31,603
Total	16,012	12,601	12,578					41,191

EULIMNERIA

1926	1,052	889						1,941
1927	2,200	4,251	2,720					9,171
Total	3,252	5,140	2,720					11,112

APANTELES

1925		1,075						1,075
1927		904						904
Total		1,979						1,979

DIOCTES

1927	460							460

MACROCENTRUS

1927	2,053							2,053

MASICERA

1927	653	172						825

PHAEOGENES

1927	1,994							1,994

ZENILLIA

1927	59	556						615
Grand total	81,403	166,558	45,364	12,119	1,609	8,926	6,745	322,724

TABLE 5.—*European corn-borer parasites liberated in Michigan, by town, year, and species*

[Recoveries indicated by asterisk]

MICROBRACON

Year	Number of individuals liberated in—							
	Erie	Monroe	Richmond	Flat Rock	La Salle	Jackson	Mount Clemens	Total
1926	19,600	11,458	15,079					46,137
1927	4,100	59,840	16,840	10,500		9,455	8,440	108,975
Total	23,700	71,298	31,719	10,500		9,455	8,440	155,112

EXERISTES

1926	*8,093	*6,752	2,793					17,638
1927	5,782	8,462	4,122	1,847	1,964	1,682	1,910	25,769
Total	13,875	15,214	6,915	1,847	1,964	1,682	1,910	43,407

DIOCTES

1926	207							207

PHAEOGENES

1926	1,161							1,161
1927	2,218							2,218
Total	3,379							3,379

EULIMNERIA

1927	2,777	2,582	*2,195					7,554

MICROGASTER

1927	8,631	2,275	5,711					16,617

APANTELES

1927		3,625						3,625

ZENILLIA

1927		3,278						3,278

MASICERA

1927		318						318
Grand total	52,669	98,590	46,540	12,347	1,964	11,137	10,350	233,497

TABLE 6.—*European corn-borer parasites liberated in New York, by town, year, and species*

[Recoveries indicated by asterisk]

Year	Number of individuals liberated of—						
	Microbracon		Exeristes	Microgaster		Apanteles	
	Town		Town	Town		Town	
	Hanover	Brant	Brant	Hanover	Brant	Hanover	Brant
1924		25,000	2,662				
1925		8,500	*2,963				
1926	6,800	1,000	*5,350				
1927	32,500	3,593	2,014	789	206	1,076	125
Total	39,300	38,093	12,989	789	206	1,076	125

TABLE 7.—*Miscellaneous liberations of European corn-borer parasites*

Locality	Number of individuals liberated of—									
	Microbracon		Exeristes		Apanteles		Microgaster		Eulimneria	Macrocentrus
	In 1926	In 1927	In 1926	In 1927	In 1926	In 1927	In 1926	In 1927	In 1927	In 1927
Pennsylvania:										
North East	6,300		2,450							
Mill Creek				2,000						
Erie		11,930		1,983						
Indiana:										
St. Joe		11,000	1,374	5,170						
Goshen		1,948								
Illinois: Sherbornville		3,635		362						
Ontario: Chatham [1]					435	1,021	819	27,427	6,719	1,049

[1] French material via Arlington. Canadian-bred material not shown.

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