Mr. Hunter stated that the farmers in the section where his experiment was tried were anxious to have it repeated this year.

A LARGE SCALE EXPERIMENT IN THE CONTROL OF THE COTTON BOLL WEEVIL

By W. D. Hunter, *Washington, D. C.*

(Withdrawn for publication elsewhere.)

A paper was read as follows:

THE ECONOMIC BEARING OF RECENT STUDIES OF THE PARASITES OF THE COTTON BOLL WEEVIL

By W. D. Pierce, *Washington, D. C.*

The utilization of parasites in the control of injurious insects generally has taken only the form of introduction from other localities or from foreign countries. Notable instances may be cited in the introduction of *Scutellista cyanea* from Africa into California to combat the black scale (*Saissetia oleae*), and the very recent introduction of this same parasite from California into Hawaii, there to attack a different species of scale in the same genus. The successful introduction of *Rhogas lefroyi* from southern India into the Punjab by Mr. Maxwell Lefroy in order to restore the former condition of control of the bollworm by this species, which was killed out by the cold winter, and the more important fact that where introduced the parasites regained much of their former control is another example of the same kind. Mr. F. M. Webster, in a paper read before this association last winter, cited a number of important cases of valuable parasites in the control of cereal and grain crop insects.

Contrary to earlier suppositions, it is now apparent that parasites and predatory insects bear a very considerable part in the control of the boll weevil. It is important to note that the boll weevil parasites are indigenous species that have been attacking native weevils, but which now, in many instances, seem to be transferring their attention to the great enemy of the cotton plant. Since the control by these inimical insects can be aided by several distinct methods of practice, it is considered justifiable to present the following remarks:

The preliminary studies which have been necessary in order to perfect any methods of economic treatment have involved the collection and individual examination of infested cotton forms during 1906 and 1907 which have contained over 54,000 weevil stages, exclusive of eggs and very young larvae killed by the proliferation of plant tissue. These were gathered at many places over an area of approxmately 200,000 square miles, at many times and are representative of all the component biological or geographical regions infested by the boll weevil in the United States.

During 1907 the average control of the weevil by parasites was ten per cent against four per cent in 1906. They are not, however, the principal element of control. Out of 62 per cent mortality in 1907, 32 per cent was due to heat and other climatic conditions, while 20 per cent were killed by predatory ants. This gives then 30 per cent as the sum of insect control.

The utilization of these insects belongs in three distinct groups of economic treatment. The most important group consists in the application of strictly cultural methods to farm practice and is therefore under the control of every cotton grower. The next group takes advantage of the known rotation of hosts and also belongs under farm practice. The third group is the simple introduction of parasites and is really in many cases preliminary to the two preceding.

The first mentioned group of methods involves early planting, wide spacing, and the use of determinate, short limbed, square retaining varieties of cotton, as explained in the following paragraphs.

The study of the activity of the parasites on weevil stages in different conditions demonstrated that the most favorable condition for parasite work was the dried hanging square. It appears that when the weevil attacks the squares or bolls the plant produces a corky absciss layer which causes the infested form to fall to the ground. There is a decided tendency among certain varieties and less so in all varieties to fail in forming a complete absciss layer and hence the infested part is caused to hang. When this has become dry, it affords the best possible condition for parasite attack since most Hymenopterous parasites require heat and light for successful work. During 1907 the average parasite control in hanging squares was 30.45 per cent, in fallen squares 4.67 per cent, in hanging bolls 5.44 per cent, and in fallen bolls 2.5 per cent. This positive demonstration of preference contributes a suggestion for economic application. It may be possible that plant breeders can develop a variety of cotton which will have this tendency in such a marked degree, that the possible parasite control will exceed the total control by all causes in varieties which shed all infested forms. At present the total control in hanging and fallen squares does not greatly differ.

Careful studies have demonstrated a preference for squares fallen in the sun over squares fallen in the shade, and for fallen squares on the prairie over fallen squares in wooded country. The reason is obvious enough. The parasites choose the dryest and lightest condition to be found. These very valuable observations give strong confirmation to the value of the cultural methods, in particular the recommendations that the cotton be planted in wide rows or checked and that determinate varieties and varieties with the least amount of foliage be used.

A comparison of fields in like conditions, except for the time of planting at several different places, shows that the earliest planted field in each case fared the best through the early part of the summer at least. This is believed to be because of the rotation of hosts by the parasites, and the possibility of the hibernated parasites attacking the boll weevil as the first or second spring host in the earliest planted fields, and the necessity for one or more generations on other hosts in the latest planted fields. The fact remains, however, that early planting is advantageous.

The second group, or control by the rotation of hosts, consists of the encouragement of the spring host plants for co-host weevils, the elimination of summer host plants in order to force over the parasites, and the fall destruction of the cotton plant to insure hibernating co-hosts for the parasites.

At present the average percentage of parasitism is very variable for localities quite close together. This is directly due to the very peculiar distribution of the parasites. No one species is of primary or even secondary importance over the entire infested territory. Six species are known to hold these positions in various portions of our territory. They are, in order of greatest importance *Bracon mellitor, Catolaccus incertus, Eurytoma tylodermatis, Microdontomerus anthonomi, Cerambycobius cyaniceps,* and *Cerambycobius n. sp. Bracon mellitor* is predominant in Texas except in the central and eastern portions. *Catolaccus incertus* appears as most important in south Texas and Louisiana. *Eurytoma tylodermatis* is at its best in north central Texas. *Microdontomerus anthonomi* is very important in central Texas. *Cerambycobius cyaniceps* predominates in northeast and east Texas and in northwestern Louisiana. The new species of *Cerambycobius* is known to occur only at Victoria, Hallettsville and Brownsville, Texas, and Alexandria, Louisiana. *Microdontomerus* is a new genus of the torymid sub-family *Monodontomerinæ* and furnishes the first species in that family known to attack Coleoptera. This species was new to science in 1906 and a very insignificant factor in the control of the boll weevil. In 1907 it appeared on places carefully watched in 1906 and where it was not found before and this year became of real importance. The new species of *Cerambycobius* in the same manner is struggling upward for recognition. The rapidity with which these new parasites have adapted themselves to the boll weevil, together with the facts that parasite attack begins within two weeks of the invasion of new territory by the boll weevil, and that six new primary parasites were added to the list during 1907, has caused us to conclude that change of host relationships is not an uncommon thing in at least some groups of parasitic insects.

The peculiar distribution of the parasites and the appearance of new parasites each year, prove that the boll weevil is not the original host of any of them in this country. In other words, the parasites are all native insects and hence are derived from native hosts. With a few exceptions these native hosts are more or less closely related to the boll weevil. *Bracon mellitor* is recorded from three species of Lepidoptera and from seven species of *Curculionidæ*. *Catolaccus incertus* has been bred from two species of *Bruchidæ,* and thirteen species of *Curculionidæ*. *Eurytoma tylodermatis* has been bred from *Bruchidæ* and *Curculionidæ*. *Cerambycobius cyaniceps* is known as a common parasite of *Cerambycidæ, Bruchidæ,* and *Curculionidæ*. *Microdontomerus anthonomi* attacks one species each in the *Bruchidæ, Anthribidæ* and *Curculionidæ*. The new species of *Cerambycobius* also attacks species in these three families.

The presence of these parasites on neighboring weevils has afforded opportunity for an extensive study of weevil biologies in which over 125 weevil species have been more or less intimately studied. Some of these weevils have ranked as injurious species in literature and others of equal importance have never received economic mention. The study of the biologies and parasites of these species has produced several points of value, all of which will be published as rapidly as time permits.

From the standpoint of the boll weevil problem, it is of course essential that such an important point as the diversity of host relationships should be utilized economically. The first phase of this diversification is an adjustable rotation of hosts, which, of course, varies in consecutive years just as the variable climate affects the seasons, and as other conditions affect the abundance of the host plants. The parasites in the main attack weevils of few generations and consequently must have several species of hosts in a season. When a parasite matures, it evidently seeks as its host the most abundant related host species and attacks that. The boll weevil is the predominant weevil species in Texas and is therefore the recipient of all parasites in doubt, so to speak, about their next host. When the cotton is late, it is necessary that there be from one to three generations of parasites on the spring weevils, thus producing a good supply of individuals at the time the boll weevil begins work. It is, however, best that the boll weevil receive the earliest generation possible in order to prevent a division with the other hosts. To insure the proximity of parasites to the cotton field in early spring, it appears advisable to have plants such as dewberry or blackberry in hedgerows, or to have red haw trees near. In the first case the strawberry weevil, *Anthonomus signatus,* is quite generally distributed and serves as an available host for *Catolaccus incertus.* The *Crataegus* trees are the food plants of three or four species of weevils which are co-hosts with the boll weevil.

During the summer season, there is an extensive series of host weevils in neighboring weeds which can be made to give up many parasites, if the weeds are cut when at their height, about twice during the summer season. The practice of making hay in the vicinity of cotton will bring about similar results. The principle is that the parasites will be forced to seek new hosts and will take the predominant related host—namely, the boll weevil. This is not a theory, for it is substantiated by definite experiments on the cotton farm at Dallas.

Adjacent to one edge of the Dallas experimental farm was a high hedge of *Ambrosia trifida* infested by *Lixus scrobicollis,* which is usually highly parasitized by *Eurytoma tylodermatis.* In 1906 this portion of the field showed less than three per cent parasitism due to this species in hanging squares. At the time of cutting the weeds, check examinations were made and two weeks later another was taken, showing a considerable gain in attack by *Eurytoma,* which netted over 30 per cent. The careful records kept on this field preclude the possibility of ascribing this result to any other cause.

In southern Texas where the predominant trees are leguminous, any cause which would tend to check the fruiting of the huisache and mesquite in alternate years or at irregular periods, would tend to cause an overthrow of the normal habits of the many parasites of the bruchids in the pods and drive them to the boll weevil. Our attention was forcibly called to a particular field at Victoria with high parasitism, where the presence of the new *Cerambycobius* on the boll weevil was first noticed and was definitely traced to the huisache trees which had failed to fruit this year.

The most important of all the cultural suggestions for control of the boll weevil is the early destruction of the cotton stalks. Owing to the probability that the parasites can hibernate better when attacking the native weevils, this practice seems advisable in order to drive the parasites over to other hosts in time to insure their establishment. Having safely disposed of an important element of control and secured its reappearance, the stalks can be burned about fifteen days after cutting, thus establishing another important method of control. The total gain is greater than that to be had by allowing the parasites to hibernate on the boll weevil.

Finally there remains the third group of parasite methods, known as direct propagation, including the transfer of breeding material or parasites, the use of field cages for infested squares, and the establishment of new ant colonies.

After locating places where a very high percentage of parasitism prevails, either on the boll weevil or on other weevils, large quantities of infested material may be gathered and transported to the laboratory or to experimental fields where the parasites may be directly hibernated. In case of the existence of secondary parasites, the material must be placed in breeding cages in the laboratory. As this is a common practice, thoroughly understood by all entomologists, it need have no further treatment. It has proved of direct and immediate value when tried.

A similar method of treatment is at hand for all planters. They may gather infested cotton squares and place them in 14 to 18 mesh wire screen cages in the field with the assurance that all parasites and only a small portion of the weevils will escape, thus by a simple measure increasing the *pro rata* of parasites.

Since the little fire ants are very important enemies of the boll weevil, it is desirable to have some way of increasing their usefulness. It appears that they are very fond of fly larvæ in fresh manure and transfer their colonies to it frequently, and that by boxing this manure the colonies may be secured very easily. The method has not yet been tested. The time of swarming is the critical time for establishing colonies, for then a single queen is sufficient.

In conclusion it may be said that a decided gain is apparent in the amount of parasite control, that the cultural methods of cotton cultivation are most favorable to parasite propagation, that the host relations of the boll weevil parasites can be more or less easily changed, that immediate results have been obtained by the release of parasites, and finally that the present investigations are bringing to light evidence that must cause important modifications of some of the accepted ideas as to the host relationships of parasites.

The next paper presented was entitled: