PRESIDENT C. GORDON HEWITT: I will now call on Mr. Kelly to read his paper.

THE TOXOPTERA OUTBREAK IN 1916

By E. O. G. KELLY, *Bureau of Entomology, Wellington, Kan.*

(Withdrawn for publication elsewhere)

PRESIDENT C. GORDON HEWITT: Is there any discussion?

MR. T. J. HEADLEE: I want to ask Mr. Kelly what evidence he has that the artificial introduction of parasites has accomplished little?

MR. E. O. G. KELLY: I think the evidence was in the total destruction of all those fields into which parasites were introduced.

MR. T. J. HEADLEE: That is like the chinch bug fungus. Its artificial introduction is apparently useless. Why is it not practical to kill the green-bug with spray?

MR. E. O. G. KELLY: It might in ordinary years be all right to kill them with a spray. I indicated in my paper that Mr. McColloch arrived in Wellington on the 30th of April at which time *Toxoptera* was scarce. On the 15th of May, just fifteen days later, there were several hundred thousand acres of oats devastated in that locality, as I believe Mr. McColloch can corroborate. It would be impossible to get spraying material and machines into action to cover the territory where the pests spread so rapidly. It was just like a fire starting in a dry heap. Nothing could stop it.

MR. G. A. DEAN: It might be of interest to know that at Bedford where these parasites were taken, they occurred in enormous numbers. In one field covering a considerable area, they were present by millions, far beyond a number any one could think of introducing. Just across the road, there was a field in which *Toxoptera* had totally destroyed the greater part of the grain.

PRESIDENT C. GORDON HEWITT: I will now call for the paper by Mr. W. J. Phillips.

REPORT ON ISOSOMA INVESTIGATIONS

By W. J. PHILLIPS, *Entomological Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C.*

The Division of Cereal and Forage Insects of the Bureau of Entomology began to gather data on the species of *Isosoma* infesting grains and grasses in 1904. From 1904 to 1906 inclusive, collections of mature infested grain and grass stems were made in most of the states east of

the Rocky Mountains, and a large amount of material was reared from these collections. From data thus secured it became evident that in order to establish definitely the identity and economic status of a species a large amount of careful and accurate breeding under control conditions would be necessary. Little was accomplished along these lines until 1912, since which time the writer has secured a large amount of valuable data on this most interesting and difficult group. These observations throw a flood of light on the economic importance of the *Isosoma* or joint worms, and clearly indicate that *I. tritici* is one of the most important pests of wheat in the Eastern States. The average farmer often confuses it with the Hessian fly, since the writer has had farmers tell him repeatedly that Hessian fly was injuring their wheat and upon examination it proved to be *I. tritici*. If wheat is badly straw-fallen before harvest, the farmer usually attributes the damage to the fly without examination.

Successful breeding of the many species of *Isosoma* in confinement is accomplished only under the most trying difficulties. A number of different types of cages have been tried, with varying degrees of success. There are two cages that have given fairly good results, though they are by no means perfect. One (Pl. 8, figs. 1, 2 and 4) consists of a wooden frame 3 feet square by 4 feet tall, two sides of which consist of a stout sash fitted with four large panes of glass. One of these sides is a hinged door the full size of the sash. The three other sides are covered with the best grade of cheese-cloth on the inside and $\frac{3}{8}$ -inch mesh galvanized iron wire on the outside, to prevent the cloth being torn. The other cage (Pl. 8, fig. 3) consists of glass cylinders 9 x 15 inches and 11 x 24 inches, respectively, with cheese-cloth cover over the top. Plants are potted in 10-inch and 12-inch flower pots and the cylinders placed over them. These cylinder cages should be shaded.

One of the greatest difficulties in breeding *Isosoma* arises from the fact that the plants must mature, and it seems very difficult to provide normal growing conditions for the plant and, at the same time, confine these tiny insects. Aphids also greatly complicate the situation and in spite of the utmost care some will gain entrance and in a short time threaten the life of the plants. Furthermore, the *Isosoma* are constantly disturbed by the aphids and do not succeed in ovipositing. With two exceptions the different species have but one generation a year, therefore, should misfortune overtake some of the cages, a whole year is lost.

There are eighteen species of *Isosoma* occurring east of the Mississippi river, seventeen of which the writer has reared in confinement from adult to adult, and has thus learned some of the main facts

concerning their life history. The other species has refused to breed. Other members of the Division have, from time to time, sent infested grass stems from various points in the Western States, from which additional species have been reared. Strange as it may seem none of the strictly western species will breed in confinement here in the East, though repeated attempts have been made to rear some of them. On the other hand, *I. tritici*, which is the most economically important species in the East, has not been found in the great wheat belt of the West. No satisfactory solution of this problem has as yet been worked out. When this is done it may offer valuable suggestions for the control of the species here in the East. There are twenty-three distinctly recognizable species known to the writer at present, occurring throughout the United States, 5 of which appear to be strictly western species, 12 strictly eastern and 6 that overlap. There are undoubtedly a large number of new species among these, but no attempt has as yet been made to describe and name them, nor will this be attempted until a critical examination has been made of all types of American species.

Quite a striking illustration of what may be a new species is one that the writer has had under observation since 1912, having reared it from wheat stubble collected in Pennsylvania, New York, Ohio and Michigan. This species has been reared only from galls in the leaf-sheath surrounding heads of wheat, and there are occasionally root-like growths from the base of the gall downward (See Pl. 9, fig. 2). The head is always empty, no grain ever developing in plants thus attacked. The late Prof. F. M. Webster has repeatedly described to the writer the root-like projections he often used to find at the base of some galls. At that time he supposed these galls to be the result of the work of *I. tritici*. In 1903 Professor Webster published a paper¹ on *Isosoma* or joint worms and illustrates injury to a wheat plant that closely resembles the work of the species in question, though he used this to illustrate the work of *I. grande*.

This new type of gall is clearly represented on the front page of Bulletin 226, published in 1911 by the Ohio Agricultural Experiment Station, although it was intended to illustrate the work of *I. tritici*. The plant is affected in an entirely different manner by *I. tritici* (Pl. 9, fig. 3), and the two species also differ both structurally and in their life-histories. *I. tritici* pupates in the fall, males occur in abundance, and the galls are always in the wall of the stem; the former species pupates in the spring, no males having occurred in three years continuous rearing, and the galls always occur in the leaf-sheath surrounding the head and there are occasionally root-like

¹U. S. Dept. Agr. Div. Ent., Bul. 42, p. 18, Fig. 5.

growths at the base of the gall. The species has undoubtedly been present in the Eastern States for many years and entomologists simply assumed that these galls were those of *I. tritici*. This is not at all strange or unusual since anyone but those very familiar with the group may easily confuse a number of the species.

Prof. R. W. Doane describes a species from Utah that forms galls in the leaf-sheath surrounding the head of wheat, as *I. vaginicum* n. sp.¹ Upon request Professor Doane kindly sent specimens of his species and they were received just as this paper was being prepared. They agree in every structural detail with the species that occurs here in the East. The effect upon the plant, as described by Professor Doane also agrees entirely with the injury as noted here in the Eastern States.

A number of interesting facts have come to light as a result of cage breeding with individual species. One of the most important is that, up to the present, no species can be induced to breed on any other plant than its own particular host. This fact was ascertained by making repeated efforts to rear in confinement a given species in plants other than its own host. Before this could be attempted, however, sufficient breeding had to be done to definitely establish the identity of a species. It seems now to be a definitely established fact that the three species occurring in wheat cannot be induced to breed in any other plant. The same is true of those occurring in rye and barley, and on down the list. This is a very important economic fact, since it simplifies greatly measures for control.

Elymus species is by far the most favored host with *Isosoma*, from which no less than seven species have been reared. Wheat and *Agropyron* sp. come next with three species each; rye and blue-grass (*Poa pratensis*) follow with two each; barley, timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), *Poa* sp., *Festuca* sp., and *Bromus* sp., have a species of *Isosoma* common to each.

The list just mentioned contains new species and may not and very probably does not include all species that have been previously described from this country. Some species that were very common years ago are almost extinct today, as seems to be the case with *I. hordei*. This species was evidently very numerous and destructive many years ago in the barley growing sections of the East, and today it has almost or quite entirely disappeared from these localities. This seems to be directly traceable to the greatly decreased acreage of barley over a large part of this territory. This is also probably true for the species occurring in rye. Whenever a certain grain crop ceases to be grown consecutively in contiguous fields, the future of the species

¹ Jour. of Econ. Ent., vol. IX, No. 4.

infesting the crop becomes seriously threatened. Heretofore it has been generally accepted as a fact that the different species of *Isosoma* infesting the small grains could and did infest the wild grasses. All evidence now shows that if a species of *Isosoma* is to maintain its existence, it must be supplied continually with its own particular host. Therefore, when planning control measures in the future for a particular grain-infesting *Isosoma*, we do not need to concern ourselves about the presence or absence of any other grain or grass crop or any of the wild grasses.

Oviposition of *Isosoma* is an interesting operation from many points of view. In the first place, the position the insect assumes in relation to the stem at the time of oviposition clearly indicates whether it is a gall-forming species or one that inhabits the center of the stem. The gall-forming species always takes a position facing downward (See Pl. 9, figs. 5 and 6) while those inhabiting the center of the stem always face upward when ovipositing. *I. tritici*, a gall-forming species, inserts its ovipositor almost parallel to the long axis of the plant stem instead of perpendicular as would appear from external observations. Three to five minutes are required to deposit one egg by this species. The ovipositor is then almost withdrawn and reinserted in a different channel. This performance may be repeated until seven or eight eggs have been deposited without the ovipositor ever having been entirely withdrawn from the original point of entrance, and the entire operation may require as long as thirty to forty minutes, or even longer. The individual may then proceed to the opposite side of the stem and insert several more eggs. Occasionally there may be two individuals ovipositing within a quarter of an inch of each other. As compared with the gall-forming species, *I. grande*, form *grande*, a species occupying the center of the stem, inserts its ovipositor almost at right angles to the stem, the egg often being placed within the cavity. This species requires three to six minutes to complete oviposition, then withdraws her ovipositor entirely and usually goes to another internode. *Grande*, however, does not insert more than one egg at a point, but occasionally two may be inserted in the same internode about a quarter of an inch apart, in which case one larva proceeds to destroy the other.

Isosoma tritici, when ovipositing, forces the ovipositor between the fibrovascular bundles, and the egg, which has a long petiole and a very flexible chorion, is then forced through the ovipositor in the form of a long thread. As soon as the point of the egg reaches the enlarged cavity made by the ovipositor its contents flow to that point and the egg soon begins to assume more nearly its normal shape. The petiole is then apparently gradually forced in, as the ovipositor is

slowly withdrawn, since the petiole is never found lying straight but is folded back upon itself at the end of the egg, the egg finally resting with petiole down the stem but entirely within the plant tissues. The entire egg is more slender and the petiole is much longer after oviposition. Stems have been dissected, after previously killing the female in the act of oviposition, and the position of the egg noted in relation to the ovipositor. *I. tritici* eggs require ten days to hatch, though the period of incubation varies with the temperature, cool weather retarding hatching. The larvæ molt at least three times and probably four. This can be ascertained by noting the change of shape of the larva, the development of the mouthparts and the number of cast skins, or molts. As many as three cast skins have been found in a single cell with an immature larva. The gall begins to form before the egg hatches and greatly disarranges the position of the fibrovascular bundles, which undoubtedly explains why the stems fall. From the time the larvæ are hatched until they are about two-thirds grown the tissues at the point where the galls occur and immediately above and below, are very juicy and softer than at other points along the stem and remain so until the larvæ are about grown, when the galls become much harder and very woody. As the fibrovascular bundles are badly disarranged by the galls, the stem does not have the rigidity at this point it otherwise would have if no galls were present. The plants soon become topheavy, especially if the galls are in the basal joints, and will lodge or fall with the first wind or rain. The stems usually bend over immediately above the gall, since the galls are just above a joint and the stem is slightly more rigid at that point. These galls interfere seriously with the flow of sap and a large amount is undoubtedly intercepted and used as nourishment by the larvæ, thus impoverishing the kernels of wheat.

I. tritici larvæ require approximately three weeks to reach maturity after hatching, or a month from oviposition, the time depending largely upon the temperature. *I. grande*, form *grande*, larvæ reach maturity in less time, since they emerge later and the weather is warmer.

Twelve species have been tested and all will breed parthenogenetically; eight are normally so, producing females continuously, males rarely occurring. In fact, one species has been reared continuously through a period of three years and no males have appeared. Apparently the males are not highly thought of among the eight species just mentioned since the females never pay the slightest attention to them when they do happen to be present. The other four species are not ordinarily parthenogenetic but will reproduce in this manner, the resulting offspring always becoming males. It is very probable that all our species, could they be tested, would prove to be parthenogenetic.

Although the different species of *Isosoma* refuse to accept a substitute for their own particular host their parasites are not so conservative, several of the more important ones being very cosmopolitan in their tastes. Thus it will be seen that the majority of the *Isosoma* are of either direct or indirect economic importance, since a parasite can much more easily maintain itself where there are a number of convenient hosts available.

A long list of parasites have been reared from *Isosoma*, the majority of which are new. The life histories of only a few of these parasites have been worked out in any detail. One of the most interesting ones thus far encountered is *Eurytoma pater* n. sp. The larva is a true parasite in its early stages, the final stage being completed on plant tissue. The parasite pierces the small tender gall and places its egg on the *Isosoma* larva. When the egg hatches the host larva is about a fourth to a third grown. By the time the parasite consumes the *Isosoma* larva it is scarcely a third grown and the only alternative is for it to finish its development on plant tissue, which at that time is very soft and succulent. These larvæ do complete their development in the same *Isosoma* cell, since they seem incapable of migrating to nearby cells to prey upon other larvæ. Therefore, as stated previously, it seems that they must and do complete their development on plant tissue.

The most important parasites of *I. tritici* are undoubtedly *Ditropinotus aureoviridis* Cwfd. and *Homoporus chalcidophagus* Walsh. There are two others, *Eurytoma pater* n. sp. and *Eurytoma bolteri* Riley var. *parva* n. var., are probably next in importance. Immense numbers of *I. tritici* are killed nearly every winter by extreme cold. Another active agency in the control of *I. tritici* is a tiny mite, *Pedi-*

PLATE 8

- Fig. 1. *Isosoma* breeding cage with door closed.
- Fig. 2. *Isosoma* breeding cage with door open.
- Fig. 3. Pot cage for *Isosoma* breeding.
- Fig. 4. *Isosoma* breeding Experiments at Charlottesville, Va.

PLATE 9

- Fig. 1. Sheath dissected from the head of wheat, showing the galls in the sheath and not in the stem.
- Fig. 2. Shows typical galls of the species that forms galls in the sheath surrounding the heads of wheat.
- Fig. 3. Typical galls of *Isosoma tritici* in wheat. Note that the galls are in the stem itself.
- Fig. 4. Plants showing typical injury from the species that forms galls in the sheath surrounding the head.
- Fig. 5. A gall-forming *Isosoma* inserting ovipositor.
- Fig. 6. A gall-forming *Isosoma* ovipositing.

culoides ventricosus Newport. Indeed, if it were not for the natural agencies of control the farmer would be either obliged to abandon wheat growing in the states east of the Mississippi River or adopt drastic measures of control.

One of the most promising measures of control of *I. tritici* at present in some of the Eastern States is to plow under wheat stubble as soon after harvest as is possible, prepare a fine seed bed and sow the clover and grass in August or September instead of seeding in the wheat in the spring. The writer does not have sufficient data as yet on this point to make a definite statement but it seems very promising. Liberal applications of commercial fertilizer or well-rotted barnyard manure will enable the plants to largely overcome the injury.

There seems to be little hope for beneficial results from burning the stubble. This was attempted for two winters in Indiana and at no time, when the ground was frozen, could the stubble be burned.

The writer hopes to have the opportunity this winter of making a thorough examination of the types of the various American species and will then describe any new species he may have, after which he will gladly identify *Isosoma* for anyone for the privilege of using the data and retaining any uniques or a small series of any that may belong to a new species.

PRESIDENT C. GORDON HEWITT: If there is no discussion, we will proceed to the next paper by Mr. G. A. Dean.

RESULTS OF TEN YEARS OF EXPERIMENTAL WHEAT SOWING TO ESCAPE THE HESSIAN FLY¹

By GEO. A. DEAN, *Entomologist of the Kansas State Agricultural College and
Experiment Station*

The time that wheat should be sown to escape the fall brood of the Hessian fly and the time that it should be sown to produce the maximum yield are problems that have been and are still receiving much attention from nearly every student of these subjects. In a state like Kansas, producing an enormous wheat crop, that may equal one fifth of the production in the United States, as in 1914, and in a state

¹ Contribution from the Entomological Laboratory, Kansas State Agricultural College, No. 23. This paper embodies the results of some of the investigations in the prosecution of project No. 8, Kansas Agricultural Experiment Station. The writer desires to acknowledge the valuable assistance of J. W. McColloch, assistant entomologist, for much of the work and the careful supervision of the field experiments. He also desires to express his appreciation of the valuable services of Prof. C. E. Call and members of his staff in the Department of Agronomy.