CIRCULAR No. 241 OCTOBER, 1932
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

LEAF HOPPERS INJURIOUS TO CEREAL AND FORAGE CROPS

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INTRODUCTION

The leaf-hopper enemies of cereal and forage crops have not been accorded the same notice that some other groups have received, but there is good reason to assume that the losses they occasion, especially in meadows and pastures, are so considerable that they deserve much greater attention than they have been given.

In early publications, including a report to the Division of Entomology in 1890 (*14*)[1] and a paper by Osborn and Ball (*21*), a number of species occurring in the central part of Iowa were treated with reports of some experimental studies in control. The most complete discussion of the group, however, is contained in a publication issued by the Bureau of Entomology in 1912 (*19*), from which considerable portions of this circular are taken and condensed, in which the writer brought together the results of studies in the group and especially the details of an extensive survey under the auspices of the bureau during 1909 and 1910. In this circular much new information is made available regarding the life histories of these insects, the conditions under which they thrive, and the best methods that have been devised for curbing their numbers and activity.

There are frequently so many species involved in the injury that there has been a tendency, even among entomologists, to consign them all to a limbo of undetermined species whose habits, life histories, and food relations were unknown.

[1] Italic numbers in parentheses refer to Literature Cited, p. 33.

The majority of the species are not only very inconspicuous, often being protected by close resemblance to the objects around them, but they are very active, jump quickly when disturbed, and can not be caught without difficulty except in a close-meshed net; when in flight they may very readily be mistaken for other insects except by an especially practiced eye.

Among many farmers they pass as the "fly," which usually means the Hessian fly (*Phytophaga destructor* Say), and they have been very commonly called the "green bug" by mistaken references to *Toxoptera graminum* Rond., which has had such general notice in the daily press. In some localities, notably in the northwestern wheat section, the term "green bug" has apparently been used very commonly for leaf hoppers in the absence of the real Toxoptera.

NATURE AND EXTENT OF INJURY

These insects are very widely distributed, affect a variety of cereal and forage crops, and must cause in the aggregate very extensive losses, which are quite generally overlooked or not fully appreciated for various reasons. One reason is that their work is so insidious, and its results, except where the insects occur in unusual numbers, so difficult to appreciate by ordinary observation that it is very likely to pass unnoticed. Another is that injury caused by these insects is very commonly charged to other agencies, either to other insects, to parasitic fungi, to drought, or possibly even to frost, because in many instances the insect itself escapes notice.

Like other members of the order Hemiptera, such as the squash bug (*Anasa tristis* DeG.), the chinch bug (*Blissus leucopterus* Say), aphids, scale insects, etc., the leaf hoppers secure their food, and incidentally occasion injury, by sucking the juice of the plant. The mouth parts consist of a beak or proboscis, inclosing slender thread-like piercing organs which are thrust into the plant and through which the plant juices are drawn into the stomach. The result of their feeding is a wilting or shriveling of the plant cells that are thus depleted of their contents, sometimes a curling of the leaf or the distortion of the adjacent parts, and in some cases a discoloration of the surface. This sometimes becomes a factor in protecting the insect, especially when the color of the insect and that of the injured plant cells is the same. Probably the most familiar examples of this kind of work are those of the wilting noticed following attacks of the squash bug or the chinch bug, the whitening of grapevine leaves attacked by the grape leaf hopper (*Erythroneura comes* Say), or the coloring and curling of leaves infested by aphids.

On grasses and grains the attack is most commonly noticed in the form of wilted or discolored blotches on the leaves or stems. It was described by Webster as a combination of punctures and slitting. Sometimes, in bluegrass particularly, it results, as the writer believes (*15*), in the condition known as "silver top," a whitening of the entire upper part of stem and head, though this particular condition is in some parts of the country undoubtedly due to attacks of the grass thrips (*Thrips striatus* Osb.)

Another point to be noted is connected with the parasitic fungi that are frequently associated with the leaf hoppers. It seems quite possible that these fungi may be assisted by the leaf hoppers in their

distribution or entrance to the plant tissues. In works on the sugarcane leaf hopper in Hawaii (*3, p. 107; 12, p. 21*) the insect is credited with increasing attacks of the fungus. A similar condition is presented in the case of the fungous rice blast, which, according to Fulton (*8*), gains entrance to the plant tissue through punctures of *Oebalus pugnax* Fab.

In recent years much progress has been made in the determination of the relation of leaf hoppers to plant diseases, and such notable cases as the curly top in beets, carried by the beet leaf hopper (*Eutettix tenellus* Baker), and the yellows of asters, which has been shown to be carried by the 6-spotted leaf hopper (*Cicadula 6-notata* Fall.), have brought the injury by these insects into much greater prominence. It is very possible that many other plant diseases may be found to have leaf hoppers as necessary factors in their introduction to the plant hosts. The leaf-hopper pests of the grasses, clover, alfalfa, and soybean deserve thorough study with this possibility in view.

Still another phase of injury is to be noted in the effect produced upon a seed crop by the attacks of leaf hoppers on the blossom or the newly forming seed. Puncture of the unfertilized blossom will easily make the pollination useless, as will also the sucking of a small portion of the sap from a newly set seed cause it to wither or prevent its maturity. Injuries of this sort in wheat, timothy, clover, alfalfa, etc., are probably of much greater frequency than is generally supposed.

Whatever view may be taken as to the extent of damage and relative importance of these insects, all who have studied the subject will agree that the puncturing of the tissue and the removal of the plant juices must result in more or less loss to and drain on the plant. Their importance then will rest more on the abundance of the insects that may attack any particular plant. It is evident that an insect which simply pumps away the juices of the plant may go on with this operation, constantly draining the plant and reducing its rate of growth, without attracting the attention of the cultivator unless the injury passes the point where the drain begins to cause actual wilting, withering, or visibly unhealthy condition. Nevertheless, this drain must show in reduction of the crop, lessening of available pasturage or forage, and actual loss, none the less real because difficult to estimate in dollars and cents.

In some estimates based on the abundance of insects actually collected in given areas it has been claimed that from 25 to 50 per cent of the growth of grass may go to feed these leaf hoppers and still all this loss may occur without meadow or pasture actually showing by wilted or withered plants that such a drain was occurring. Only in periods of drought (and then this loss may commonly be charged against a dry season) is the effect such as to be noticeable in meadows and pastures.

Some idea of the number of these insects can be gained from various observations and counts and some appreciation of it by walking through a pasture or meadow and noticing the clouds of minute leaf hoppers that spring into the air in one's pathway. Estimates based on various captures in Iowa amounted to from a half million to a million insects per acre. In testing a hopperdozer for

catching them the writer secured in some instances more than a million per acre, and obviously this number must fall short of the number actually present. Some careful estimates based on actual captures over plats 5 yards square were made at the writer's suggestion in the fall of 1908 by V. L. Wildermuth. These captures were in timothy and bluegrass-timothy pastures, and although it can not be assumed that all the leaf hoppers in the given area were caught, the average for all these captures gives a result of about 1,000,000 per acre, in some cases as many as 2,000,000 per acre being recorded.

CROPS AFFECTED

While the present survey is intended to cover the various cereal and forage crops, it must, for a number of reasons, be more complete for those that are of most general culture. In general, it may be stated that all of the crops belonging to the grass family and most of those in common cultivation belonging to the legumes are infested by one or another, often by many, species of leaf hoppers. The abundance and corresponding injury vary greatly with these crops for different parts of the country and under different cultural conditions, as also with different seasons, so much so that general statements for annual crops are hardly applicable here. One of the most obvious conclusions, however, is that the greatest drain occurs where, owing to continuity of crops or by close association of common food plants, there is offered an exceptional opportunity for the survival and increase of the insects from generation to generation through a season or during a series of years.

GENERAL HABITS OF LEAF HOPPERS

There are several features in the general habits of these insects which may be discussed for the group, although there are certain ones in which each particular species must be considered by itself. In their food habits, as has been mentioned, there is a wide diversity, some species affecting a great variety of plants, others a very few. The various species, however, agree pretty generally in attacking the leaves or the freshly grown portions of the stem of the plant, making their punctures where they can secure the sap with the greatest ease, thus affecting the growth of the more succulent portions.

In many instances the insects show a distinct adaptation to certain parts of the plant, to the extent that the shape and color of the body blend with the part upon which they are feeding, notably in cases where the coloration coincides with the markings at the joints of the stems, causing the most perfect resemblance of the insect to the joint. Some of the insects affect the seeds or blossoms, others cluster near the ground, and some have even been reported as affecting the roots, but only a very few species have been noted attacking the plant in this manner.

There is no distinct adherence to a particular plant except during the earlier nymphal stages or for certain species which have aborted wings and are, therefore, unable to fly. Practically all of the species, however, jump with great facility and if disturbed will jump and may come to rest on the ground or some adjacent plant. A general habit which is of importance is a tendency of the insects to disperse

to other kinds of plants during the last nymphal stage. It has been noticed that many species which seem to be very closely restricted to particular plants in the earlier nymphal stages scatter freely during the last nymphal stage to different kinds of plants, showing a distinct disposition to vary their diet.

General migrations of the insects are not common, but there must be local migrations from field to field, especially at times when the food supply becomes scarce or unsuitable on account of the ripening of the plant. At such times there may be a general dispersal of the insects; for instance, from wheat fields to adjacent grasslands or in the fall from grasslands to near-by fields of fall wheat, oats, rye, etc., which furnish a much more attractive food for that season. Migrations by flight for long distances are unknown for any of the species, but some recent observations indicate the possibility of their carriage in wind currents of the upper air. There has been observed in many cases a distinct tendency for the leaf hoppers to gather at night around conspicuous lights, and although it is not known whether all of the species are thus attracted, so many different ones have been noted as being attracted by artificial lights that it may fairly be presumed that the habit is quite general. Many instances are on record where immense numbers have been observed assembling around lamps or street lights, and often this must result in the destruction of great numbers of individuals.

HIBERNATION

The different species of leaf hoppers do not all hibernate in the same stage. Those species which pass the colder months as adults lay their eggs in the spring. Some species hibernate as partly grown nymphs, and in other species, particularly the grass-infesting forms, hibernation is apparently common in the egg stage. The stage in which hibernation takes place is of the greatest importance, especially in connection with methods of control based on the treatment that is possible in late fall and in early spring. It is also important in the case of those forms which become active in mild weather during the winter and are thus exposed to conditions which may affect their survival.

LIFE HISTORY IN GENERAL

So far as has been determined, the eggs of the species affecting grains and grasses are deposited in the leaves or stems of the food plants of the nymphs. The method of deposition has not been accurately noted in very many instances, but, for such as have been observed, it consists in the pushing of the eggs by means of the strong ovipositor into the margin of the leaf or into the spaces between the leaf and the stem. The number of eggs deposited probably varies with the species. The number has been recorded in the case of a few individuals, and in some cases it must be considerable, as the insects multiply at a rapid rate. Hatching takes place either in a few days after oviposition or, in the case of hibernating eggs, early in the following spring, and consists simply in the emergence of the nymph from the broken end nearest the outside of the opening into which the egg has been forced.

All the species of leaf hoppers pass through a series of molts, usually four or five in number, and in these various instars they show a gradual progression toward the adult form. In some cases these early forms are sufficiently like the later and adult stages to be recognized as of the same species, but more commonly there is such a difference in their appearance that it is only by rearing them from stage to stage or by careful comparison of the different stages that it is possible to make out the correct life history. The molting occurs at uniform periods and consists in the shedding of the entire epidermal covering, this usually remaining attached to the surface of the plant as a thin, transparent film. The insects increase in size and soon change from the light color of recent emergence to the darker or more distinctive color common to the species. All, of course, pass through the egg and nymphal stages, and the last nymphal stage may be considered as corresponding to the pupal stage of insects in general.

The number of generations in each season is also a variable matter, but there are commonly two generations each season, in some species probably three, and in a few it is known that only a single generation occurs. This is, of course, an important factor in the economic importance of the species, since each additional generation provides for an immense increase in the numbers of individuals and also makes much less effective the special conditions of culture required for the crop on which it feeds.

RELATION TO ENVIRONMENT

The leaf hoppers constitute one element in a very complex association of plants and animals, including birds, mammals, reptiles, toads, insects, and spiders, and it is only by the recognition of this relation that any very adequate appraisal of their proper place in nature and of their importance in the economy of cultivation can be suggested. Primarily they are associated with certain kinds of plants upon which they depend for their sustenance, and the abundance of leaf hoppers will be affected, necessarily, by the abundance of the food plant and its availability as food material. An undue increase of the leaf hoppers, which should result in the diminution of the food supply, must necessarily affect the possibilities of multiplication and cause a certain reduction in the number of insects. This is, however, by no means the only relationship, for a large number of other organisms, both plant and animal, will affect the problem. The occurrence of different birds, spiders, and insects which prey upon the leaf hoppers will naturally reduce their numbers and to that extent favor the plants which serve as their food, whereas the presence of herbivorous animals, grasshoppers, cutworms, etc., serves to reduce the available food supply.

Aside from these dominant forms there are also various fungous parasites which attack both insects and plants and which play their part in the complex of which the leaf hoppers are such a conspicuous element. Furthermore, the minute insect parasites which attack the leaf hoppers add their part, tending to keep the latter reduced in numbers. The relation of these and other direct parasites will be considered under the general head of natural enemies.

NATURAL ENEMIES

That leaf hoppers maintain a fairly average abundance from year to year, for the most part causing no perceptible devastation, is due to the fact that there are so many different natural agencies tending to reduce their numbers or to keep them in check. Of these natural enemies, birds, spiders, and predacious and parasitic insects would appear to be the most important and to require careful consideration. It seems improbable that leaf hoppers are affected to any extent by mammals, except as eggs may be swallowed by forage-eating species—cattle, sheep, etc. The only forms which would seem likely to feed upon them are the moles, and these confine their work so largely beneath the surface of the ground that it is doubtful whether they would secure many of the leaf hoppers.

There are records in the Bureau of Biological Survey of leaf-hopper remains in the stomachs of a bat (Myotis), the common mole, a grasshopper mouse, the skunk, and the domestic cat. The bat must have taken the leaf hoppers on the occasion of a nocturnal flight and not from their host plants, and the other cases would appear to be accidental rather than a regular habit of feeding.

BIRDS

Birds would undoubtedly be thought of as an important factor in the natural control of leaf hoppers, and it would seem that they might feed very commonly upon these insects. The most complete records in this line are those accumulated by the Bureau of Biological Survey of the Department of Agriculture, which has for many years been making a record of the contents of birds' stomachs. Besides the published data concerning certain species of birds, that bureau has an immense collection of unpublished records, and these have been very kindly put at the writer's disposal for the purpose of this study. Practically all of the data here presented on this point were derived from this material. Although these records do not, in most cases, give the particular kinds of leaf hoppers which are fed upon by certain species of birds, there should be represented, of course, the kinds of leaf hoppers which were abundant at the time and place indicated. The birds, of course, make no discrimination between species, except as these might appear in greater numbers or prove an easier prey.

While at first thought birds might be considered as a most important element in control of these insects, a closer study reveals many reasons why they must depend upon them but little as a food supply. Even with this more conservative view in mind, however, the actual condition as represented by the records of the Biological Survey is rather disappointing, since they show that for practically all of our common birds the leaf hoppers constitute so small a portion of the food supply that birds may be considered as almost negligible in any consideration of the natural agencies of leaf-hopper control. It is, however, important, both as a matter of record and for the benefit of future workers, that the actual condition as indicated by these records should be made available in brief form.

Early records (*19*) showed that there were 119 different species of birds whose stomachs contained remains of leaf hoppers in various

proportions from a trace to 80 per cent. Considering only these species, there were only 770 out of about 28,000 stomachs examined (about 1 in 36) which contained leaf-hopper remains, and in the majority of cases the leaf-hopper material amounted only to from 1 to 10 per cent. But including all species of birds, out of about 47,000 stomachs examined these 770 would be less than 1 out of 60, so on a most liberal estimate only about one-tenth of 1 per cent of the food of birds can be said to be leaf hoppers.

Later records showed 1,435 stomachs out of about 80,000 to contain leaf-hopper remains. These represented 175 species, and of 35 of these species the remains were found in 10 or more instances. In a number of cases from 20 to 50 leaf hoppers were found in a single stomach, and in one instance, that of a barn swallow, about 1,000 were found. It may be concluded, however, that the previous statement that birds are practically a negligible factor in the control of these pests holds true. This does not, however, affect the conclusions as to the value of birds in destroying other kinds of insects, especially such larger forms as grasshoppers, cutworms, army worms, and sod worms.

SPIDERS

The great abundance of spiders in pastures, meadows, and grain fields is often most manifest by the immense number of webs that may be seen, especially on dewy mornings. These webs, however, tell only part of the story, as there are a great many species of jumping and running spiders which construct no webs to capture their prey, and among these there are to be counted some of the most numerous and active insect feeders of the fields. These spiders are often taken in large numbers when sweeping for leaf hoppers, and that they feed readily upon the hoppers is proved by finding them with hoppers in their grasp within a few seconds after their capture in the net. Direct observation on unconfined individuals is difficult, since both spiders and leaf hoppers are so hard to watch, but enough has been seen to justify the opinion that spiders are among the most widely distributed, constant, and effective agents in keeping leaf hoppers in check.

A very extensive study of the food of spiders has been made by Bilsing (*2, p. 232*), in which he found that spiders were very effective in capturing leaf hoppers, and that they occur in such large numbers as to be a very important factor in the reduction of the numbers of these as well as other insects. In mentioning one particular species, a common meadow spider, *Agelena naevia* Walck., he says:

> The number of these spiders in any given area is enormous. In order to determine how numerous this spider is, I counted them on several different areas. In a clearing which was full of stumps and brush piles and which is an ideal place for this spider, I counted them in midsummer when most of them were nearly full grown. On an area of two and one-half acres, nine hundred and thirty-four individuals were counted. On a brush pile six feet in diameter, I counted thirty-two of these spiders. Another count was made along a lane for a distance of one hundred and thirty-two feet, the count being taken on both sides of the lane between the ditch and the fence. In this distance there were two hundred and sixty spiders.

Spiders therefore may be considered as a very important and fairly constant factor in the reduction of leaf hoppers and their presence in the fields as of distinct advantage.

INSECTS

The insect enemies of the leaf hoppers are not so numerous as they are for some other groups of insects, but there are a number which may be considered as of sufficient importance to notice.

PREDATORS

Among the predacious forms perhaps the most abundant and efficient are the little bugs of the family Nabidae, some of which are found in great abundance in the meadows and pastures where the leaf hoppers occur. The most abundant of the species is *Reduviolus ferus* L., which occurs throughout the United States and may be found in almost every kind of grassy land. That it is a frequent predator upon the leaf hoppers is indicated by its attack upon them when they are taken together in the net, although seldom found with the insects actually impaled upon their beaks in the field. It is probable that they puncture and suck the blood of the insect very quickly and discard the dead body so promptly that they are not found with them actually impaled. There is no question but that they draw upon the leaf hoppers as one source of their food supply, and they may be one of the principal agencies in keeping the leaf hoppers in check.

Another group which is less notable is the genus Geocoris, in the family Lygaeidae. These are minute flattish bugs, with prominent eyes, which occur as widely distributed common insects on the ground among the grasses and other low-growing vegetation. Their attack upon leaf hoppers has been reported by various observers, and during the season of 1910 a definite instance of the species *Geocoris decoratus* Uhl. was noted by Herbert T. Osborn, of the Bureau of Entomology. This species was found at Wellington, Kans., in a number of instances with small leaf hoppers impaled on its beak, and numbers of dead leaf hoppers were found in the vicinity.

PARASITES

In the parasitic insects affecting the members of this group is found another constant factor of control, and one which is perhaps far more important than is readily appreciated. Among these forms are numbers of Hymenoptera, Diptera, and Strepsiptera. Of the Hymenoptera the most abundant parasites are included in the families Proctotrypidae and Dryinidae and in the genera Gonatopus and Dryinus. These parasites attack the nymphs more particularly, but are often found upon the adults and are conspicuous, inasmuch as for many of the species the parasitism takes the form of an external sack-like structure in which the larva develops on material sucked from the body of the host. In some of our native species of leaf hoppers these parasites have been found in something like 20 per cent of the individuals, so that it is evident that they must constitute a quite distinct check.

An extensive series of records showing the parasitism of these forms is found in the reports of the Hawaiian Experiment Station, in the papers of Perkins (*23*) and others in connection with investigation of leaf hoppers affecting sugarcane. Many species were collected and reared from leaf hoppers occurring in the United States

for the purpose of introducing them into the Hawaiian Islands in hopes that they might prove of service in control of the sugarcane leaf hopper (*Perkinsiella saccharicida* Kirk.).

An extended study by Fenton (*5*) upon the dryinid parasites of leaf hoppers has shown that these insects are of very common occurrence, that many species have no other hosts, and that they are very widely distributed in the meadow and pasture lands of many regions.

Among the Diptera a genus, Pipunculus, is recorded as parasitic upon leaf hoppers, and Giard (*10*) is authority for the opinion that these are in general parasites, especially of the family Jassidae (Tettigoniidae). These have not been recognized to any great extent in this country, and it can not be said to what extent they may be of service here, although a species in this genus has been taken by Professor Knowlton in considerable numbers from the sugar-beet leaf hopper, *Eutettix tenellus*.

The order Strepsiptera, or the twisted-winged insects, includes some very peculiar and remarkable parasites, numbers of which have been recognized as occurring on leaf hoppers. These parasites are so minute and inconspicuous that they are very seldom observed, and there are no very positive data as to the numbers in which they may occur, so although they may be a very constant factor in control, it is doubtful if they can be credited with very much influence in reducing the numbers of the hoppers.

REMEDIAL MEASURES

The usual methods of control for leaf hoppers may be discussed here under the general head of remedial measures, but some of the particular modes of treatment, applicable to certain species and to particular conditions of culture, must be discussed in connection with the species concerned. Practically all of the measures available must be adapted to the seasons or conditions of crop, and, consequently, to advise any general method which would be applicable in all cases is impossible.

CULTURAL METHODS

Under the head of cultural methods the effect of different plans of cropping or the rotation or alternation of different crops may be discussed. This is, in many cases, one of the most effective means in keeping leaf hoppers in check. The general immunity of spring wheat in the northwestern wheat-growing regions is quite certainly due to the effect of the methods of culture prevailing there, which do not permit of a general infestation of the wheat fields; for during the time when the insects would scatter for oviposition, most of the fields to be planted in wheat are bare and furnish no attraction. In the case of the northern wheat regions, as in Pennsylvania, another condition is evidently responsible for the lack of infestation, and this is the extreme cleanliness of the culture, the fields being cultivated so close to the fences that scarcely any grassland remains, and the source from which the dispersal of the leaf hoppers generally takes place is thus done away with.

A very different condition is presented in fields which have been continually in grass for a number of years. In such cases the hop-

pers occur in immense numbers, even as high as a million or more to an acre, and the resulting injuries become serious. Contrasting this with fields in grass for only one or two years, it appears quite evident that rotation tends to eliminate the leaf hoppers and that it requires two or three years of continuous grass to give opportunity to the leaf hoppers to reach their greatest abundance. In sections where there is a general plan of rotation in which grass occupies certain fields for not more than one or two years, injuries are restricted to such an extent that they may be ignored. A striking instance of this was noticed on the farm of the North Dakota Agricultural College, where a pasture that had been in bromegrass for several years was badly infested, while near-by fields recently planted in grass were nearly free. When permanent pastures are in woodland, where rotation is obviously impracticable, it is evident that other measures must be adopted if control is to be secured.

The possible control of the species by the cutting of the grass depends upon an adjustment of the mowing to about the time when the insect is present in the egg stage or in such an immature condition that it is unable to migrate from the fields. At such times close mowing of the grass will remove such eggs as may be included in the leaves or stems and by exposing the young nymphs to a shortage of food as well as to the direct action of the sun serve very materially in bringing about their reduction. A somewhat similar effect may be produced by the very close grazing of the grasslands during a certain period, arranged if possible to correspond with that of the egg deposition of the more common species, followed by a period of absence of stock from the field so that the grass may have a period of rapid growth.

BURNING DRY GRASS

Undoubtedly one of the most effective means of destroying the eggs of the leaf hoppers in the fall or early spring is the burning of the dead grass wherever this measure is practicable, and it may be resorted to with the assurance that much will be accomplished. The difficulty in this treatment arises from the fact that some grasses will not withstand burning except when the ground is frozen or so wet that the heat will not penetrate the surface, and that in cases where fields are freshly seeded to grass the young plants may be injured by this treatment. This process is, perhaps, most applicable in the prairie regions, where the accumulation of dry material at the surface of the ground furnishes abundant opportunities for the use of fire, which will destroy the eggs and hibernating forms occurring in the locality. It is also especially applicable to the alternating strips of grass, in the localities where wheat and grass are planted side by side. Direct observations of this method have revealed some good results, but it has not been generally used under conditions allowing for accurate measurement. In the prairie regions, before general settlement, prairie fires were of very common occurrence, and although it can not be determined just how much they have accomplished in the control of these insects, it is worthy of note that pasturage on these plains was of a very excellent quality and of long duration. One of the most positive evidences of the effectiveness of burning was observed in Ottawa County, Kans., on a level tract of grassland adjacent to a stream, where part of the surface which had

been burned over a short time previously was practically free from leaf hoppers while the adjacent unburnt area, under otherwise identical conditions, was abundantly infested with hoppers of several different species. Even where the areas examined were closely adjacent or the burnt patches were surrounded by unburnt grass the difference was very noticeable. This was evidently due to the fact that the burning had been quite recent, and unfavorable weather had kept the hoppers so inactive that there had been little migration from unburnt to burnt portions. With so positive a case as this, along with many others of nearly equal certainty, it seems entirely warranted to recommend burning for such pasture lands and range as can be burned over without causing other injury.

CAPTURING THE INSECTS IN HOPPERDOZERS OR TAR PANS

The direct treatment which has had the most thorough trial is the use of the hopperdozer, which consists of a sheet-iron strip, 2½ by 12 or 15 feet, coated with coal tar. The apparatus is drawn over the grass; and as the insects hop at its approach, many of them fall upon the tar surface and are killed. In a number of tests of this method at the Iowa Agricultural Experiment Station it was found that, in pastures having a normal infestation of leaf hoppers, the insects could be captured at the rate of from a half million to a million to the acre, which very appreciably reduced the number occurring in the treated fields. Probably three-fourths or more of the hoppers occurring in any particular area were captured by one or two treatments of this kind. It was found that this treatment could be applied to best advantage during the latter part of the afternoon on sunny days, when the insects jump most readily and could be caught in the greatest numbers. In one experiment with this plan, a plat was treated for a season, and a comparison of the hay from this plat with that from an equal untreated area showed an increase for the treated plat of more than 50 per cent.

Two fenced lots of bluegrass, each containing about 1¾ acres, were used in another experiment. One plot was treated, leaf hoppers being collected from it by the hopperdozer in large numbers at various times, and upon this plot cattle, varying in numbers, had been pastured at different times throughout the season for a period of about 73 days. On the other, untreated, a single cow was pastured. A comparison of the number of available hours of pasturage per animal on each plot showed that the treatment gave a gain of 68 per cent in the capacity of the pasture. However, it is evident that migration of these insects from adjacent areas would tend to reduce the advantage of the treatment, especially in a small field, and that the greatest advantage could be secured from treating an entire tract, so that there would be no opportunity for reinfestation from adjacent lands. The expense of this method of treatment is not great, the cost of materials being very small, and the labor of man and team, or tractor, dependent on locality or season.

SPRAYING

With the present spraying apparatus, it is possible to apply broadcast sprays of insecticides over any pasture lands or meadows, or even cultivated fields, where the crop is not so far advanced as

to prevent access to the surface of the land. Such treatment, so far as the mechanical features are concerned, would be entirely practicable. At the North Dakota Agricultural Experiment Station such a broadcast sprayer is used for treatment of the fields to kill weeds, and, if a contact insecticide were used, it would seem that very effective results could be secured.

THE MORE IMPORTANT SPECIES OF LEAF HOPPERS AFFECTING GRAIN AND FORAGE CROPS

THE YELLOW-HEADED LEAF HOPPER

The yellow-headed leaf hopper, *Draeculacephala reticulata* Sign., an extremely abundant species in the southern part of the United States, has been noticed a number of times as destructive to wheat or oats, but has never received any full discussion, and the details of its life history are not known. It was described by Signoret as *Tettigonia reticulata* in 1854 from specimens derived from Cuba and without any statement concerning its importance. Later, in 1880, it was redescribed by Riley (*24*) and named by him *Diedrocephala flaviceps*, and in connection with the description appears the note: "Numerous specimens injuring wheat and oats in Texas in 1876." There is a record of its destructive abundance in South Carolina, and the records of the Bureau of Entomology include a number of instances of its occurrence in wheat and other crops.

DISTRIBUTION

In Van Duzee's catalogue (*28*) the distribution of the species was given in 1917 as covering Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Missouri, Kentucky, Tennessee, Nebraska, Texas, Arizona, California, West Indies, and Mexico, which gives it a considerable range. The one record of its occurrence in Lincoln, Nebr., makes that the most northerly point from which there are any indications of its presence, and so remote from other recorded localities that it may be based on an exceptional occurrence. If common there, it should be found at intermediate points between this and Texas. It has been found in northern Oklahoma, but careful collecting has failed to discover it in Kansas. The other more northerly records are from Charlottesville, Va., Fulton, Ky., and Mountain View, Mo. The writer found a similar form at Yuma, Ariz., in wild grass, but this differs from the type in having a triangular spot on the vertex. It appears, therefore, that there is a northern limit for the species, and this limit is not determined by any limitation of food plants, since the species feeds readily on various plants, a number of which are common at points farther north.

PROBABLY AN INTRODUCED SPECIES

With the evidence at hand it appears quite certain that this species was introduced or migrated into the United States from a more southerly habitat. Although the species might possibly have been overlooked by early collectors, it is too conspicuous a species where it occurs for this to be probable. Moreover, the records would seem to

indicate an advance toward the north since its first appearance in the Southern States. Its original description from Cuba, 1854, precedes any record here, and the early records refer to such southern localities as Texas and South Carolina, a distribution still holding in 1894, when Van Duzee's first catalogue was published. In 1900 the species had not spread north of the Gulf States and South Carolina. That it is restricted climatically is evidenced by the slow progress made and by its northward distribution, which agrees very closely with that of the cattle tick.

FOOD PLANTS

The food plants of the species have generally been given as wheat or oats, but since these records usually come from cases of excessive abundance during the fall, it is very evident that they are based on

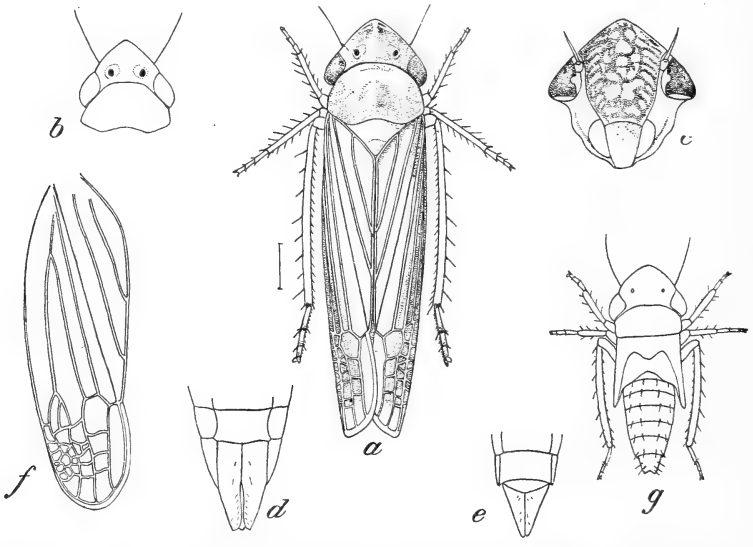

FIGURE 1.—The yellow-headed leaf hopper (*Draeculacephala reticulata*): *a*, Adult, ×9; *b*, vertex; *c*, front; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, supposed nymph from North Carolina

migrations from adjacent fields. This has been clearly determined by the finding of adults and nymphs in grass land adjacent to wheat fields at Raleigh, N. C., and at Columbia and Clemson College, S. C. At Raleigh it occurred in strips of bluegrass with other grasses; at Columbia and Clemson College particularly in Bermuda grass; and it was also found in Bermuda grass in fair abundance at Decatur, Ga. In Mississippi, Texas, Arizona, and California it was found most constantly in Bermuda grass, and this is accredited as being one of its favorite hosts; but the records are too meager to permit the assertion that its range is coextensive with this plant. Although observations are wanting, it may be very safely assumed that the eggs are deposited in some of these grasses of general distribution, that the nymphs develop upon these during early summer months, and that only after maturity do they spread from these to the wheat and oats.

DESCRIPTION

This species is one which is very easily recognized, since it differs definitely from the other leaf hoppers with which it is ordinarily associated. The structural features are shown in Figure 1. The head is of a rather bright yellow or orange-yellow color, with two light spots on the vertex, including ocelli, and the fore wings are light green. Beneath, it is of a pale yellow color, the borders of the abdomen being slightly reddish. The legs also are pale yellow.

A nymph which was referred to this species was found associated with adults at Raleigh, N. C., in the fall of 1909. This was grayish, with orange patches on the sides of the pronotum; the same form associated with adults of *reticulata* has been sent from Dallas, Tex., so the writer feels confident that this is the nymphal form.

TREATMENT

Although additional knowledge concerning the place of egg deposition and development of nymphs, and especially as to the number of generations during the year, may furnish a better basis for the recommendation of measures for control, it may very safely be concluded that the injuries to wheat and oats could be very materially lessened by attention to the various grasses growing in the waste land adjacent to cultivated fields. Mowing and even burning over all such areas should very greatly reduce the numbers of this leaf hopper, and if this is attended to before or soon after the appearance of wheat above the ground the attacks on this crop should be largely prevented.

THE TENDERFOOT LEAF HOPPER

The tenderfoot leaf hopper, *Draeculacephala mollipes* (Say), (fig. 2) was described by Say in 1831 as *Tettigonia mollipes*, among the early descriptions of American insects, and has been a very commonly observed species ever since. Nevertheless, it seems to have received much less notice from the economic standpoint than it merits. It was mentioned by Fitch in his list of insects in 1851 (*6*), but without economic discussion; in 1884 Uhler (*26, p. 249*) gave a description and also added that "the salt marshes of the Atlantic States furnish places of shelter for it, where it may be found on weedy grasses in all stages from June to October." In 1890, Garman (*9*) described it as a corn pest and spoke of it as being abundant in several stages of growth on corn on low ground, generally concealed in the hollow formed by the partly unfolded blades. It evidently occurred in different stages, as he says: "Recently matured females predominated. About half as many males occurred and about the same number of young." This occurred at the time the corn was about 2 feet in height (probably midsummer), as many as 20 leaf hoppers being observed on a single plant in some of the fields. The area affected was not large, and the insects were not often found on corn on high ground. He also mentions that the species was affected by an epidemic disease, due to an insect fungus, *Empusa grylli*. In this connection it may be mentioned that Webster has a record of the occurrence of this fungus on this same species many

years ago, the fungus being identified by Prof. Roland Thaxter at Harvard University. The writer called attention to the abundance of this species and gave a brief description of its economic status in an earlier publication (*14*), and later, in 1893 (*17*), added some facts concerning its life history.

DISTRIBUTION AND FOOD PLANTS

This is one of the most widely distributed American species of leaf hoppers, occurring throughout practically all of North America south of the strictly boreal portions of Canada. During the collections of

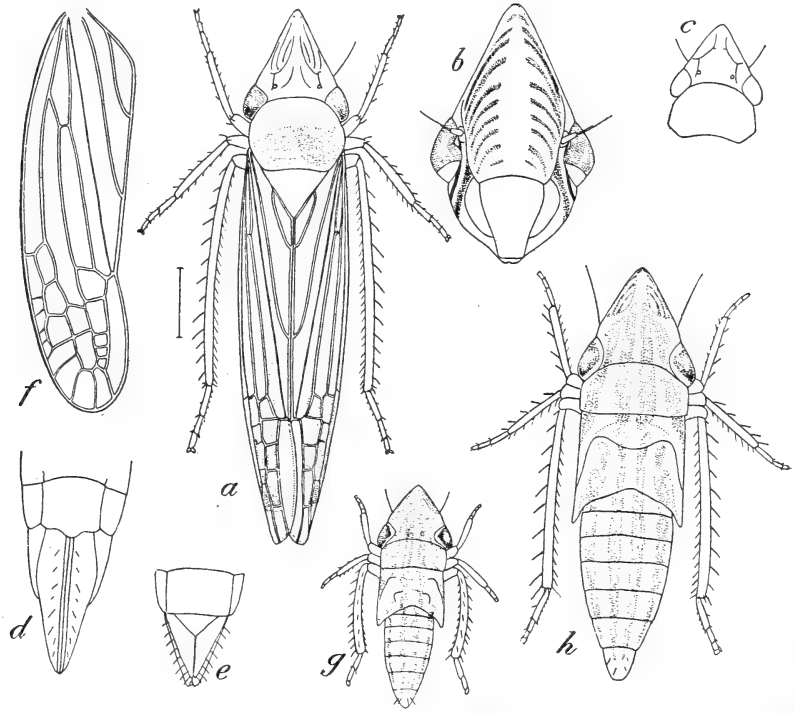

FIGURE 2.—The tenderfoot leaf hopper (*Draeculacephala mollipes*): *a*, Adult, ×8; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, *h*, nymphs

1909 and 1910 it was found at every locality visited and usually in considerable numbers. Its range in food plants is also considerable, although it has apparently a distinct preference for certain grasses growing in the moister ground. It has been taken upon wheat, oats, rye, and barley, and the list of grasses affected includes many species. Bluegrass is apparently a less favored food plant, although it is often found in bluegrass fields, especially where other grasses are present.

DESCRIPTION

The adult insect is of a bright grass-green color, quite slender in form, and when resting upon a blade of grass is very inconspicuous, in fact, can scarcely be seen unless it jumps or takes wing. The head

is very sharply pointed, of a yellowish-green color, and is marked by several very delicate oblique lines. Beneath, it is nearly black, the legs greenish, the wings a nearly transparent milky white. The female is about one-third of an inch and the male about one-fourth of an inch long.

LIFE HISTORY

It is rather curious, considering the great abundance and wide distribution of the species, that a full description of the nymphal stages has not been published. This may be due in part to the very great abundance of the species, or it may be because the nymphs, while presenting evident characters, are not particularly striking in appearance; and partly, perhaps, it is due to the general neglect of life-history studies for this group of insects. Egg deposition occurs in the fall and is at this time mainly confined to large-stemmed grasses growing in low ground or thoroughly moist locations, a selection which may be due to the more succulent character of such plants at this time or to a preference for the larger stems. Oviposition in midsummer appears to be less restricted, and apparently the eggs are placed in the borders of the leaves as well as between the leaf sheath and stem. A series of eggs collected by R. A. Vickery, at Salisbury, N. C., which quite certainly belong to this species, were placed beneath the epidermis along the margin of the leaf, the inner end of the egg extending to the midrib. Owing to parasitism, these eggs did not hatch, and the determination of the species is not absolute. Mr. Vickery, however, secured egg deposition in a leaf of corn when the insect was confined with this plant.

The newly hatched nymphs have not been observed, but nymphs of later stages have the characteristic shape of the adult, the head is sharply pointed, a little less so in the early stages, and becoming a little more acute with each of the molts. They are of light-green or yellowish color, with four dorsal parallel stripes running very nearly from the front of the head to the end of the body. These stripes diminish gradually toward the end of the body, the two outer ones disappearing at the middle of the abdomen, whereas the two central ones continue to the end. The different molts agree quite closely in appearance, except in the development of the wing pads. These in the last nymphal stages form angles extending to the back of the second abdominal segment.

There are clearly two distinct generations annually and a somewhat irregular occurrence of different stages during the fall and winter owing to the survival of nymphs and adults. Hibernation seems to occur in all stages from the egg to the adult, although the great majority must pass the winter in the egg stage. Eggs hatching in the spring give rise to nymphs which reach maturity by the latter part of June, and these adults survive until about August 20. The second generation of nymphs begins to appear about the second week in August, and nymphs are found through September, October, and November, although some individuals may become adult by the middle of September and others remain as nymphs until winter. These dates will vary somewhat with latitude, and possibly a greater number of generations may be found in the South, but no positive observations are on record for that region.

MIGRATION

Aside from the local migration which occurs in passing from field to field and the selection of attractive areas, the insect shows at times a distinct habit of migration at night. A number of instances are known where immense numbers have collected around electric lights, and this would seem to be associated with some general factor which brought them, perhaps the wind, as otherwise it would be difficult to account for the movement from their sheltered locations near the ground. Such migrations are observed during midsummer, but, so far as known, no instances of the migrations in the late fall have been observed.

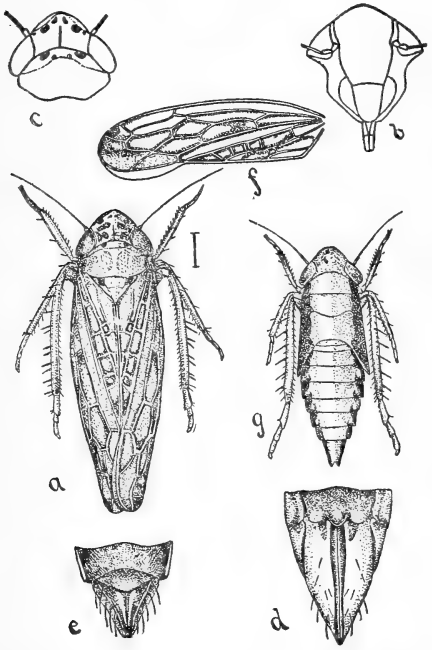

FIGURE 3.—The inimical leaf hopper (*Deltocephalus inimicus*): *a*, Adult, ×9; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, elytron; *g*, nymph. (After Osborn and Ball)

CONTROL

Available control measures for this species are suggested by its habit of selecting the coarser kinds of grass for oviposition in the fall, as it is quite possible to cut or burn such grass, and in this way the number of eggs that survive will be greatly lessened. The insect jumps very readily and may be captured in the hopperdozer quite successfully. It might also be controlled by spraying when it occurs in fields which could be run over by the apparatus.

That the species is kept in check by parasites is evidenced by the fact that eggs are parasitized by one of the minute forms, probably Trichogramma, the species undetermined.

The occurrence of the fungus *Empusa grylli* may also be considered a distinct factor in the control of this species, although practicable means of extending its operations can not be suggested. Doubtless the activity of predacious species of insects and spiders plays a very considerable part in keeping the numbers down, and birds should be expected to take a larger proportion of these leaf hoppers than of the smaller species.

THE INIMICAL LEAF HOPPER

The inimical leaf hopper, *Deltocephalus inimicus* Say (fig. 3), is one of the most widespread and injurious species among the leaf hoppers, but nevertheless it has received comparatively little notice in economic literature. It was first described in 1831 by Say (*25*, *p. 305*), who states in connection with the description: "When in the

larva state this species is said to depredate on the roots of wheat. Several specimens were sent me by Professor Green, in the year 1822, who received them from a farmer of Virginia." This would place the recognition of the species as an injurious pest as far back as 1822, over a century ago. Fitch (*6*) merely mentions it in his list published in 1851, but does not seem to have recognized its economic importance, and the next mention of it from an economic standpoint appears to have been not until 1890, when the writer (*14*) called attention to its abundance and its destructiveness in Iowa in connection with other insects, and later described the general appearance of the nymphs and published some details of the life history (*17*), and described the treatment for it, especially with the hopperdozer (*16*). Webster (*29*) in 1896 gave some information on the life history of the insect.

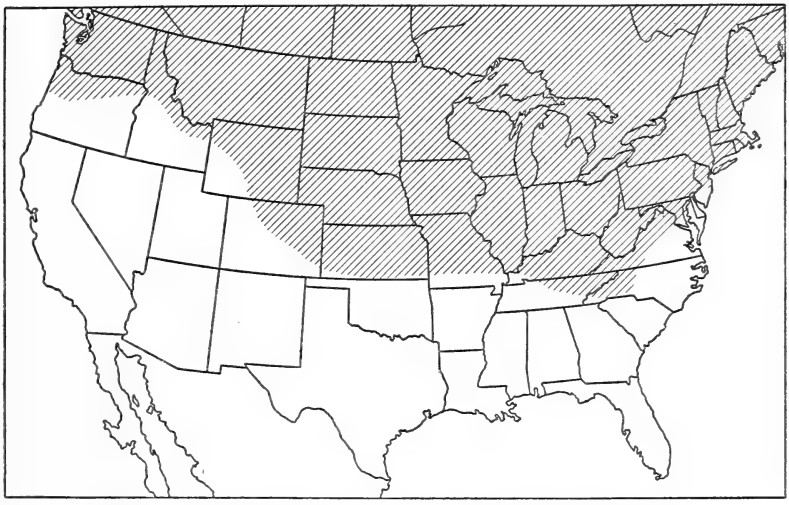

FIGURE 4.—Map showing distribution of *Deltocephalus inimicus*

DISTRIBUTION

The species is one of very wide distribution in the United States (fig. 4) and appears to be confined to this continent. Van Duzee, in his earlier catalogue (*27*), credited it to Canada and the United States west to the Rocky Mountains, but later records indicate its general occurrence all the way from Maine to Washington State and south at least to Tennessee and southwest to Kansas.

In 1909 the writer found it at practically all points where collections were made in the northern part of the country west to Washington, especially in all places where bluegrass occurred.

Its particular habitat is where bluegrass is the common pasture grass, and this is, perhaps, its favorite food plant. So generally distributed is it that it is almost impossible to sweep over any patch of bluegrass anywhere from Maine to Washington without finding representatives of this species among the leaf hoppers that are captured. Throughout most of this territory it is usually the most abundant of the species taken, and in many cases it far exceeds all

other species in numbers. In a statement of relative abundance by Wildermuth (*19, p. 15*) it was shown that this species may comprise about nine-tenths of the numbers captured. Although bluegrass and timothy are the more common food plants, the species has a wide range and has been observed on wheat, oats, millet, corn, rye, clover, alfalfa, and a considerable number of wild grasses of the Plains region. This general occurrence on different food plants makes it possible for the species to survive in almost any locality, and it is thus given abundant opportunities to migrate to any favorable crop which may grow within a reasonable distance.

LIFE HISTORY

Although the nymph was mentioned by Say in his original description, no study of the life history seems to have been made until 1892. General descriptions of the different stages have been made by the writer (*17, 18*). The eggs are deposited in the leaf or stem, especially beneath the epidermis of bluegrass, and cause very minute, blisterlike swellings. These for the winter generation remain until spring and hatch, for the latitude of Iowa, in the latter part of April and early May, there being some variation according to the season. This generation matures by the latter part of August, and adults are usually encountered from this time on until winter, although scattering nymphs are likely to occur during the fall months. No proof, however, is available of a definite third brood for the season, and eggs deposited by adults in the fall survive the winter, to renew the cycle the following year.

During the growth of the nymphs five distinct stages have been observed, the first of which, the newly hatched nymph, is rather short, with a very prominent head and a small abdomen, and without clear markings. The second stage differs in having a more elongate form of body and a definite black border along the sides of the thorax and abdomen. The third stage differs from the second only in the appearance of the wing pads, and from this stage on through the fourth and fifth stages the change consists merely in a greater intensity in coloring and relative increase in the size of the wing pads. At the end of the tibia of the hind legs there is a peculiar microscopic spatulate structure that occurs in varying numbers from the newly hatched nymph to the adult form. In the specimens studied and figured there were for the first instar 1, for the second instar 2, for the third instar 3, for the fourth instar 5, and for the adult insect 5. The adults are gray, with dark-brown or blackish markings. A very constant feature is the presence of 3 pairs of black spots, 1 pair on the vertex, 1 pair on the pronotum, and 1 pair on the scutellum. The length is about one-fourth of an inch.

The molts occurred at intervals of 7 or 8 days in specimens observed in rearing cages, and in some instances the development from the newly hatched nymph to the adult occurred in 32 days. The time of incubation for some eggs has been determined as not longer than 17 or less than 10 days. This, however, was for eggs kept in jars, and it is possible that under outdoor conditions the rate of development may be more rapid.

CONTROL

There is not much to be added to the discussion of the general control, as this species is one of the most widely distributed and is open to every remedy which has been advised for the leaf hoppers in general. The fact that it is primarily a grass insect, and that it attacks wheat, oats, and other grains incidentally, makes it possible to reduce its injuries to grain by attention to the adjacent fields. The burning of grass along the sides of the field, in fence corners, or along roadsides would in a large degree protect wheat fields from the fall migrations. The species is readily caught in the hopper-dozer, and in pastures or permanent meadows where burning is not considered desirable this or the application of an insecticide by spraying is probably the most desirable control measure.

THE BLACK-FACED LEAF HOPPER

The black-faced leaf hopper, *Thamnotettix nigrifrons* Forbes, is an abundant and very widely distributed species, occurring in a number of variations, so it has received several technical names. It was first described by Forbes (*7*) from specimens found infesting wheat and oats, but neither details of life history nor mention of its habits or distribution were given.

DISTRIBUTION

The species is distributed over a large part if not the entire northern and eastern part of the United States, having been found all the way from New York to Georgia, and west to New Mexico.

FOOD PLANTS

Although this leaf hopper has a considerable range of food plants, there is apparently a distinct preference for the annual grasses, such as foxtail or panic grasses and others, but it migrates very readily from these into wheat, oats, and other cereals and also occurs very commonly in bluegrass and timothy, especially after the withering of the annual grasses upon which it has fed earlier in the season. On this account it is one of the most troublesome forms occurring in fall wheat and oats, since it has developed in great numbers upon early grasses and, with the failing of these as a food supply, is forced to migrate, and this migration, timed with the appearance of the young and succulent plants of wheat and oats, is directed to them as the most attractive bait.

DESCRIPTION AND LIFE-HISTORY NOTES

The adults (fig. 5, *a*) are to be recognized by the rather short vertex, the margins of which are plainly rounded, and especially by a distinct row of black spots which lies next the border of the upper part of the head and bends down alongside the eyes in front. Of these spots, four are on the upper part between the ocelli, usually one on each ocellus, and two on each side between the ocelli and the bases of the antennae. Other spots may occur with greater or less distinctness on the upper part of the head, but they are too variable

to constitute good characters for recognition. The face is usually marked with numerous black bars; sometimes it is entirely black or has only a few light streaks on the lower portion. The nymphs of this species appear early in the summer, and the adults are usually to be found in numbers by the 1st of July. These adults deposit eggs from which nymphs develop during July and August, and adults appear in September and are to be found on into October and November, and in localities farther south may be taken in numbers as late as November and early December. In fact, they seem to remain active until severe cold weather forces them into inactivity.

MEANS OF CONTROL

The methods of control for this species may be based directly upon the migratory habits of the species and especially upon the fact that it develops so largely in the field grasses which are either worthless or noxious in character. In many places the mere elimination of foxtails and panics which grow along the borders or in

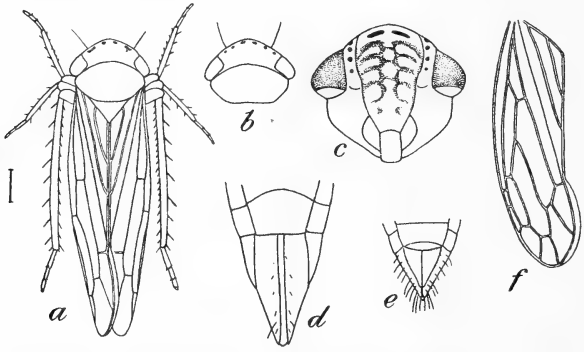

FIGURE 5.—The black-faced leaf hopper (*Thamnotettix nigrifrons*): *a*, Adult, ×10; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, wing

neglected cornfields would greatly reduce the numbers of this pest, and in some instances it would be entirely practicable to burn the borders of fields, where such grasses are beginning to wither, in time to kill the hoppers which may occur there. In the Southern States, especially where fields are often interspersed with strips of uncultivated ground, the burning or even close mowing of such strips would doubtless be of considerable service in preventing injury to fall wheat and oats. Additional knowledge concerning the actual method of deposition of eggs may add to the possible measures for control.

THE STRIATE LEAF HOPPER

The striate leaf hopper, *Deltocephalus striatus* L., has been discussed under the names *debilis*, *melsheimeri*, and *affinis* in earlier articles, but it was noticed as an economic species in 1890. It was an extremely abundant and apparently destructive species in Iowa during a number of years when it was observed in that State. It occurs in greatest abundance in bluegrass, in lawns, and upon pastures or meadows, showing a distinct preference for open and sunny situations rather than shaded locations.

DISTRIBUTION

It has a very extensive distribution, having been reported under various names from the New England States and throughout the northern part of the United States and southern Canada and is evidently a form that was reported by Ashmead under the name *harrimani* from Alaska (*1, p. 132*). It is now considered as identical with the widely distributed form occurring in Europe.

DESCRIPTION

The adult insect is of a light gray or brownish gray, often pale, but varying so much in color that it has been many times described under different names. It is nearly one-sixth of an inch long and is to be separated from *D. inimicus* by the absence of definite black spots on the head and thorax and by the slightly smaller size. The head, too, is a little more distinctly pointed. (Fig. 6.) The most positive characters are found in the genitalia, the last ventral segment of the female being short, nearly straight on the hind border, while the male valve is very much enlarged and convexly rounded, almost covering the plates, the tips of which appear as slight projections beyond its hind border.

The nymphs are of about the same form as those of *inimicus*, but differ distinctly in that the body is uniformly light yellow without the black lateral border which is characteristic of *inimicus*. The head is bluntly angled in front, and in the last nymphal stage the wing pads expand in a rather sharp angle back to the second abdominal segment.

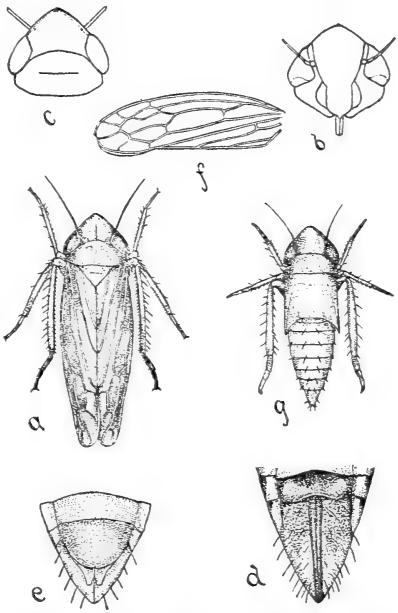

FIGURE 6.—The striate leaf hopper (*Deltocephalus striatus*): *a*, Adult, ×10; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph

LIFE HISTORY

The life history of the species has not been determined with complete accuracy and is difficult to establish because of the irregularity with which the different generations appear and the overlapping of adult and nymphal stages. On the basis of observations in Iowa, it was believed that there might be three or possibly four generations each year; and the separation of the broods, so far as they could be determined, showed adults from the middle of May until the last of June, nymphs from the first week in June until the middle of July, adults, again, from the first week in July through August, nymphs through August until the middle of September, and again adults from the middle of September through the season. The evidence is

therefore very strong that eggs are deposited in the fall, survive the winter, hatch early in the spring, and, developing as nymphs during April or early May, reach the adult condition, as observed above, by the middle of May.

CONTROL MEASURES

As the eggs are quite certainly in the leaves or stems of dead grass during the fall, winter, and early spring, it would seem almost certain that burning over the grassland where practicable would have a very positive effect upon this species. Of course, this is not possible in some cases on account of the amount of green vegetation that would prevent burning, and in other cases, if the grass is too dry, there would be danger of killing out the plants. Perhaps the best results would come from burning while the ground is frozen and at times when the upper portion of the grass is dry enough to carry fire.

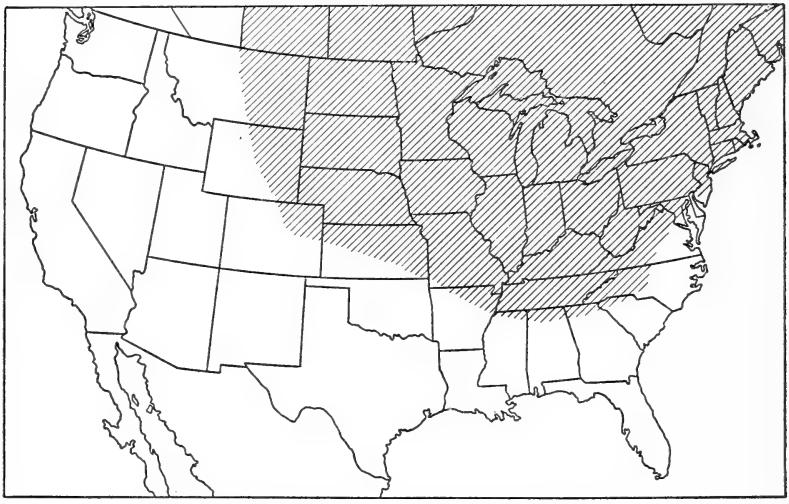

FIGURE 7.—Map showing distribution of *Deltocephalus sayi*

SAY'S LEAF HOPPER

Say's leaf hopper, *Deltocephalus sayi* Fitch, is another widely distributed species, occurring in abundance in practically all kinds of grasslands throughout the northern part of the United States, but showing a preference for bluegrass in woody pastures. It seems to have little preference for upland or low ground, except as the grass becomes dry in midsummer, when it will be found gathering more particularly in shady places or where extra moisture permits the grass to remain more succulent. It has been recorded or observed in localities all the way from New Hampshire to the Rocky Mountain region and as far south as North Carolina, Kentucky, and Kansas, and it probably has a distribution farther south at least along the Appalachians. (Fig. 7.) Its numbers are sufficient to make it a considerable pest in pastures and meadows where it occurs, although it does not have the extreme abundance noted for *D. inimicus* or *D. striatus*.

The adult insects (fig. 8, *a*) are small, robust creatures, with a rather distinctly pointed head and with the fore wings broad and rather short in many cases, exposing the tip of the abdomen beyond the end of the wings. They are dark brown, with distinct light markings and a fairly distinct band across the wing base and again back of the middle of the fore wings. They are a trifle more than one-eighth inch in length.

The nymphs (fig. 8, *g*) are rather slender and have a distinctly angular head. They are colored much as in the adult, but the arrangement of the markings is different. There is a narrow middle line of white extending from the tip of the head to the end of the abdomen, where it widens and nearly covers the tip. A broad stripe extends along the side from the eye back to near the tip of the abdomen and an indistinct narrow one extends from the inner margin of the eye, broken by white spots, one on the posterior end of each abdominal segment; a second row of dots lies midway between the first and the marginal stripe on each side.

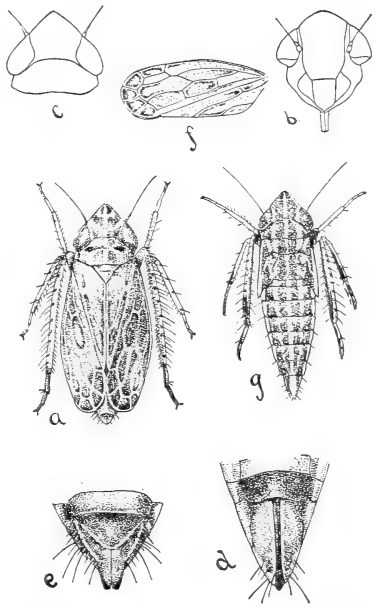

FIGURE 8.—Say's leaf hopper (*Deltocephalus sayi*): *a*, Adult, ×10; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. (After Osborn and Ball)

Although the broods are not very definitely separated, it would seem from the observations made that the first brood of nymphs occurs from May until the early part of June, the adults of this brood from the last week in May until the middle of July. The second brood nymphs are present from the last week in June until the first week in August, while the second brood of adults, beginning to appear about the middle of July, extends through August; a third brood of nymphs, appearing first about the middle of August, develops during August and September, and the third group of adults, beginning to appear in early September, survives through October. From this life history it is obvious that it will be difficult to fix upon any time at which mowing of the grass would be distinctly effective in exterminating the species; consequently direct treatment with hopperdozers or sprays or the effect of general rotation of crops must be depended upon as the principal means of control.

This species has been found to be quite extensively parasitized by the small hymenopterous parasites of the family Dryinidae. At one time at Cedar Point, Ohio, about 20 per cent of the individuals collected showed the presence of the little external sacks of these parasites. Doubtless they constitute an important factor throughout its range in keeping the species reduced in numbers.

THE DESTRUCTIVE LEAF HOPPER

The destructive leaf hopper (*Euscelis*) *Exitianus obscurinervis* Stål, was first given definite recognition as a destructive pest in the report of the entomologist of the Department of Agriculture in 1879 (*4, p. 191–193*), and in connection with this report there is given a technical description of the species under the name *Cicadula exitiosus* Uhler. While it seems impossible that the injuries of the insect should have escaped previous observation, it is probable that they were referred to some other insect or that the injury was not at that time charged to any insect. This report mentions damage during the previous winter to grain in western South Carolina, parts of North Carolina, and Georgia, and shows that the leaf hopper occurred in immense numbers and did great injury to the crops.

In observations during the summer of 1930 through the drought-stricken district of Ohio, Indiana, Missouri, and Kansas this species was the one which seems to have survived most successfully, as it was found in practically all locations where there was any vegetation sufficient to furnish a food supply. In many cases it was the only species to be found, and in some cases where the growth of alfalfa or some grasses was sufficient to give it abundant food it was found in considerable numbers. This would seem to bear out the supposition that the species has migrated into this region from the Tropics, and it shows also that it has a considerable range of host plants which permit it to survive where other species are eliminated.

DESCRIPTION

The adult insect (fig. 9, *a*) of this species is about one-sixth inch in length, the males being somewhat smaller than the females. The color ranges from dark, nearly black (especially in individuals from the Southwest) to grayish white, the wings especially being almost transparent, but showing very distinct dark veins. The head is broad, and the body tapers quite distinctly to the tip of the wings, the widest part of the body being about one-fourth the distance from head to the end of body. The eggs which were secured by dissection from an adult female are about 1.5 to 2 mm long and 0.5 mm thick, distinctly enlarged near one end and tapering to a rather distinct, blunt point at the other end. They are placed in the leaves or between the leaf sheath and stem of the plant.

Comstock states that the young hoppers when hatched are almost or precisely the same in appearance as the old ones, except that they lack the wings. There is, however, a slight difference in the position of the spots on the head and in the proportion of the parts of the body, the head appearing considerably larger in proportion, this proportion decreasing as the young insect develops. The head is broad, the eyes prominent, and there are two distinct black spots on the front portion of the head surrounded by a lighter circle, and the body is marked with grayish dots, both on the thorax and abdomen. As the nymph grows the wing pads develop at the sides and in the final stage extend back over the base of the abdomen. These characters may best be seen in Figure 9, which shows also three nymphal stages.

LIFE HISTORY

The adults of this species are found until late in the fall or even on warm days in winter, and in the Southern States doubtless remain active during a large part of the winter. It is probable, however, that the majority lay eggs there late in the fall or early in the spring. The nymphs develop in the spring, and mature individuals are to be found early in the summer. There are quite certainly two broods for all of the Northern States and probably three or more for the

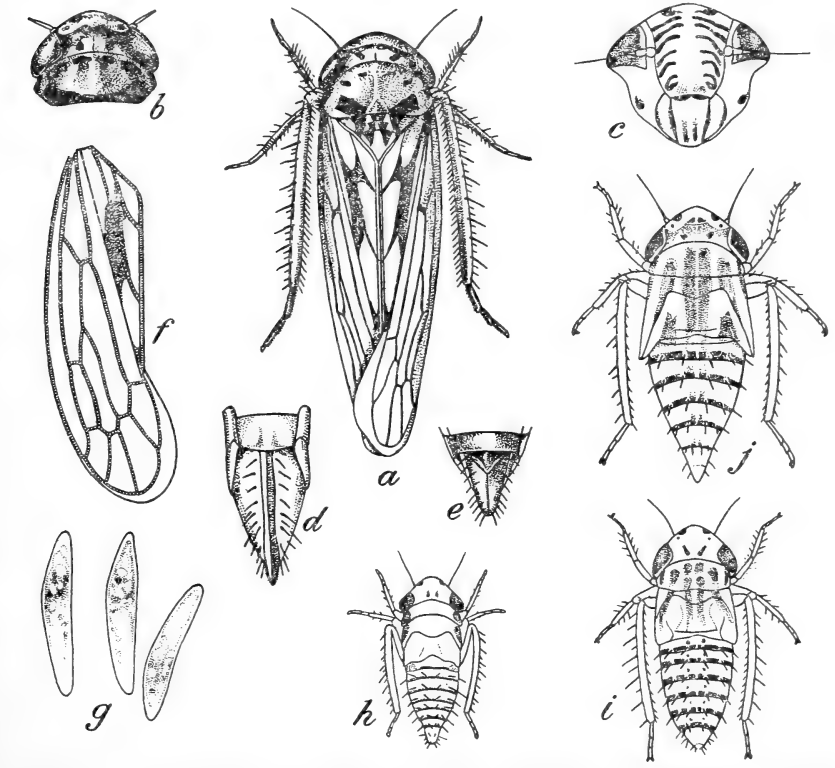

FIGURE 9.—The destructive leaf hopper ((*Euscelis*) *Exitianus obscurinervis*): *a*, Adult female, ×10; *b*, head and pronotum of male; *c*, face of female; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, eggs dissected from female; *h*, *i*, *j*, three stages of nymphal growth

southern portion of the country. The exact time limits of broods are not known and can not be readily determined because there is so much irregularity in the time of occurrence of the different forms, in that adults and young of all stages may be found at almost any time of the year.

DISTRIBUTION

The distribution of the species was given by Van Duzee in 1894 (*27*, *p. 304*) as from Maryland to Florida and west to Colorado and Texas, but later records have extended this distribution so as to

cover practically all of the United States and portions of Mexico and the West Indies. In 1909 and 1910 the writer found it in abundance at almost every point where collections were made, from the Dakotas to Washington and in the Eastern States from New York to Georgia. In the Southwest it swarmed in almost every locality from Texas to California, being one of the most abundant species met with in collections from grass, wheat, oats, and fall rye. It is quite probable that this is a southern species that has spread over the northern part of the United States in comparatively recent times, but is now well established. Evidently it is to be considered one of the most important of all the leaf hoppers when its wide distribution and possibilities for multiplication are taken into account.

MEANS OF CONTROL

The control of the species is a somewhat difficult matter for grasslands, although it can be captured in the same manner as other common leaf hoppers, but the attacks on grain, especially upon fall wheat, rye, barley, and oats, ought to be very readily prevented by attention to the adjacent grasslands at the proper time in midsummer or early in the fall before the appearance of the fall grain crops. When it is appreciated that these leaf hoppers develop entirely during the summer months in the pastures, meadows, or grasslands adjacent to the cultivated fields, it will be seen that the proper basis of treatment is to attack them in these breeding grounds. Although they may not appear remarkably abundant or seem to cause great injury in the grasslands, they are, nevertheless, draining the crop extensively, and when these plants begin to ripen or become less succulent the tendency is for the leaf hoppers to migrate into the grainfields. Since they fly very readily they accumulate in large numbers in the grainfields, and consequently produce very marked injuries. The treatment of the grassland will depend largely upon what the nature of the land is and its importance as pasture or meadow. If practicable, it may be sprayed or treated with the hopperdozer; but for rough land, especially that which is not of importance for pasture, probably the most desirable method would be to burn it over as completely as possible in September, or at about the time that the grain crops are planted. Of course some of the adults might escape by flight, but at this time a large number of the insects would be in the nymphal stages and unable to escape from the fire. The method suggested by Comstock, of utilizing lights, to which they are attracted, may prove of considerable advantage, but there has been no careful experimental test of the effect of this kind of treatment.

THE IRRORATE LEAF HOPPER

The irrorate leaf hopper, *Phlepsius irroratus* Say, is one of the most abundant and widely distributed species of the genus, occurring all over the eastern part of the United States from the extreme north to the Gulf and westward to the Rocky Mountains. It is dark brown; the surface is minutely irrorate on the vertex, and numerous fine reticulations or irrorations appear on the wings. (Fig. 10.) It is nearly one-half inch in length.

The life cycle of the species is not known in detail, but the nymphs occur very commonly in grassland, meadows, pastures, and sometimes in wheat fields during the latter part of the summer. They are rather flattened and are more or less distinctly irrorate, with minute patches on the head, pronotum, and abdomen. Figure 10, *f*, represents a nymph taken at Toledo, Ohio, associated with the adults where other species were not present. As such nymphs have in many cases been taken in association with adults of *irroratus* where the species is abundant and at widely separated localities, there is practically no doubt as to its identity.

While the species is abundant throughout the Eastern and Central States and, indeed, throughout its entire range, its economic importance is not fully recognized, since it occurs in quite general distribu-

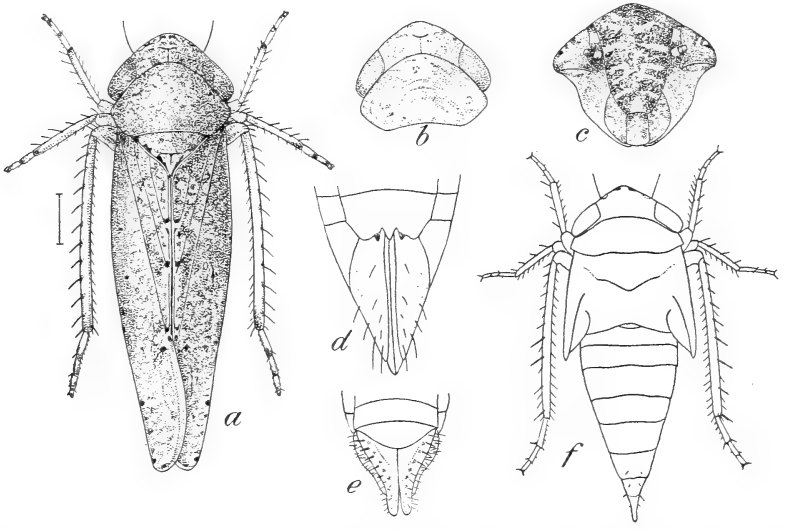

FIGURE 10.—The irrorate leaf hopper (*Phlepsius irroratus*): *a*, Adult, ×10; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, nymph, from specimen taken at Toledo, Ohio

tion and has never been recorded as swarming in any one particular place. It is hardly possible to collect leaf hoppers in any part of the country, especially late in the summer or fall, without finding an abundance of this species, and it is certain that they must cause some injury in the crops which they affect. It is found especially in wheat fields, in clover, alfalfa, and grass, and has evidently a rather wide range of food.

Since it is so generally distributed, it is not such a simple matter to control it, but it could doubtless be controlled to some extent by the burning of the strips of grassland adjacent to fences, and especially in the South this should serve as a considerable relief from its attacks on winter wheat.

THE SIX-SPOTTED LEAF HOPPER

The earliest published record of the six-spotted leaf hopper, *Cicadula 6-notata* Fall., in North America appears to be that of Forbes

(*7*) in 1885, and there is a record in the Bureau of Entomology by F. M. Webster, dated December 4, 1885, of its occurrence on wheat.

There is little separation into distinct broods, and adults are found throughout the season, probably because of the short period of development of the young. In Texas adults have been abundant as early as March 22. Webster gives a record of adults, confined on wheat kept indoors, which deposited eggs on November 11. These hatched November 27. A further note on the last-stage nymph on December 24 would indicate the passing nearly to adult stage within a period of about six weeks under indoor conditions. With present data, it seems impossible to determine definitely the number of generations during a season except for individual localities.

The adult insect (fig. 11) is of a light greenish-yellow color. The head is marked very distinctly with black dots or spots arranged in pairs; there are two round spots on the hind part of the vertex, a pair of transverse spots a little in front of the middle, and another

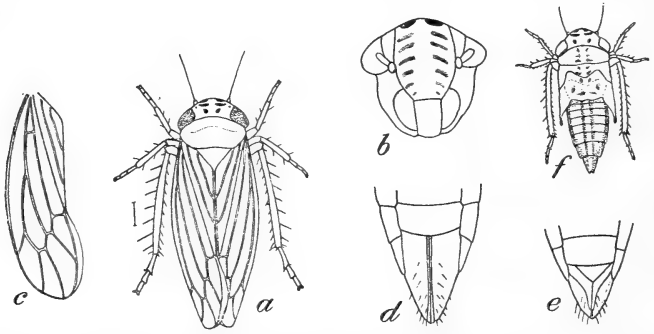

FIGURE 11.—The six-spotted leaf hopper (*Cicadula 6-notata*): *a*, Adult, ×10; *b*, face; *c*, wing; *d*, female genitalia; *e*, male genitalia; *f*, nymph

pair, also transverse, at the border between the vertex and the front. The front is marked with black curved lines, and the sutures are black. The elytra are nearly transparent, the veins showing as lighter lines near the base and darker lines toward the apex, which also is somewhat smoky. The body above is black, the border of the abdomen is yellow beneath, the rest of the body is yellow, except that the central part of the thorax and the basal portion of the abdomen are black.

The life history was studied in Maine (*20*, *p. 68*) some years ago. There seemed to be a fairly distinct migration from grasslands to oats at the time oats were in a succulent period of growth.

The nymphs are rather easily distinguished by the markings on the head, which are very similar to those of the adult. The color is usually a darker green, the head is more rounded, and the abdomen is slender. The successive instars have not been differentiated.

As mentioned on page 3 of this circular, this leaf hopper is the carrier of the virus causing the "yellows" of aster and of other plants (*11*, *p. 654*).

The ready migration may lessen the efficiency of rotation and clean culture; yet it was noticeable that very few were to be found in

fields where recent planting or clean culture was the rule. The hopperdozer treatment would probably serve in places where it can be used.

THE POTATO LEAF HOPPER

The potato leaf hopper, *Empoasca fabae* Harris, was first described by Harris, presumably from beans, later by LeBaron as a pest of apple, and it has received considerable attention at various times in this connection and as a pest of various woody plants. It is also at times very destructive to other crops, having been noted on potatoes, beans, soybeans, cowpeas, alfalfa, clover, etc., by various authors. It is credited with causing the injury known as hopperburn in potatoes, and has been reported as attacking the second crop of alfalfa, causing it to turn yellow. Various records show a ready adaptability to alfalfa, and indicate that the species must be reckoned with in the growing of this crop.

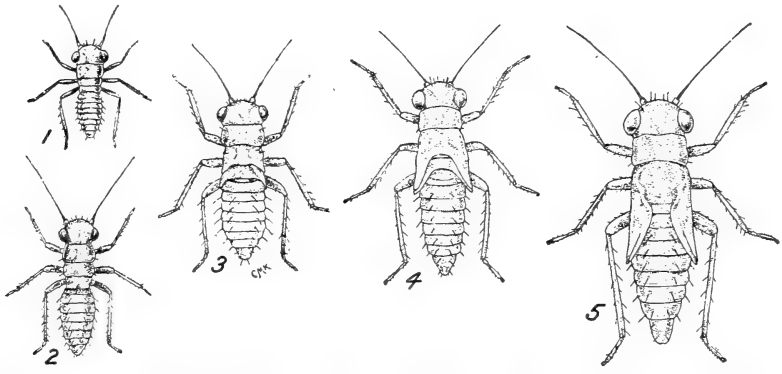

FIGURE 12.—The five nymphal stages of *Empoasca fabae*, ×15. (After Webster)

The insect is about one-eighth inch in length, of a light grass-green color, usually quite brilliant and sometimes iridescent, this color prevailing throughout the entire body, but there is a series of whitish spots along the front margin of the prothorax, usually six of them, and two whitish lines or stripes on the mesothorax which are united near the center by a transverse band, forming the letter "H." A small triangular white spot occurs on the scutellum, with a small dot on either side. The eyes are brilliant white when the insect is alive, but turn a dull brown in dried specimens.

THE NYMPHAL STAGES

The nymphs (fig. 12) are light green, often with a yellowish tinge, and are found usually upon the underside of the leaves of the plant which they infest, clustered commonly beside the midrib and main ribs, where they suck the juices of the leaf.

DISTRIBUTION

The species is widely distributed over a considerable part of the United States, but it has been determined by De Long that records west of the Plains region are to be referred to another species.

CONTROL

The control of the insect is rendered difficult because of the large variety of plants upon which it may feed, and its ready migration from one to the other. Upon potatoes and other low-growing crops the use of copper sulphate spray is perhaps the most available direct treatment, but for large areas this is rather expensive. Moreover, its most successful application is limited to times when the crop is young or short enough for the spray to reach the foliage thoroughly.

THE CLOVER LEAF HOPPER

The clover leaf hopper, *Agallia sanguinolenta* Prov. (fig. 13), is one of the most abundant and widespread species of American leaf hoppers, but very little has been done in the matter of working out its

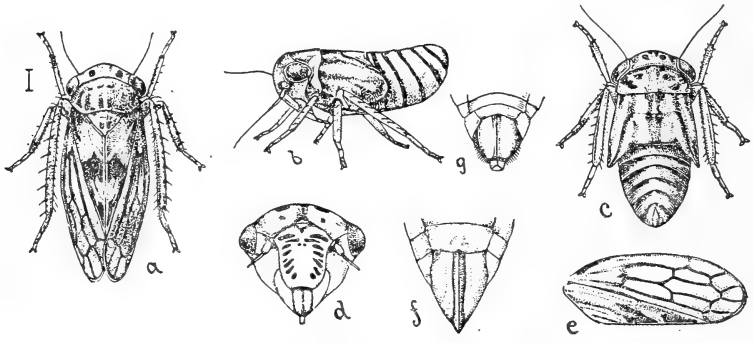

FIGURE 13.—The clover leaf hopper (*Agallia sanguinolenta*): *a*, *Adult*, ×10; *b*, *c*, nymphs; *d*, face; *e*, elytron; *f*, female genitalia; *g*, male genitalia. (After Osborn and Ball)

habits and life history, and that little has been within the last few decades. It was treated as a grass insect in 1890 in an article by the writer (*14*, *p. 29*). It was discussed as a sugar-beet insect by Bruner in a bulletin on sugar-beet insects in 1891 (*13*, *p. 68*) under the name *Agallia siccifolia*, and in the same year the writer (*22*, *p. 258*) discussed it in its various stages as a clover pest and also mentioned it as a sugar pest under the name now used.

It is a small gray insect, with dark markings, and may be recognized by reference to Figure 13.

Distribution is general from New England through southern Canada, Washington, and Oregon, and south to Georgia, Mississippi, Florida, West Indies, and Vera Cruz, Mexico, and it is also found in Arizona and California.

It affects a wide range of crops, as might be inferred from what has already been said, but it shows a preference apparently for clover, alfalfa, and other legumes, and the nymphal stages have been taken so far almost exclusively on plants of this group. The writer believes the injury in clover fields or alfalfa to be very considerable, not only in checking the growth but very probably in lessening the seed production by its attacks on the blossoms and newly forming seed.

CONTROL

Owing to the habit of adult hibernation, the winter or early spring burning of rubbish and dead leaves, in which these leaf hoppers are found, is likely to be quite effective in reducing their number. Where they occur in destructive abundance the spraying of alfalfa or clover fields directly after cutting a crop should be of distinct advantage.

It has been noticed that the species harbors considerable numbers of minute hymenopterous parasites, probably of the genera Dryinus or Gonatopus, and it is very likely that these parasites assist in keeping the number of these leaf hoppers within such bounds as to prevent very notable injuries.

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U. S. GOVERNMENT PRINTING OFFICE: 1932

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