

HAWAII AGRICULTURAL EXPERIMENT STATION.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

BULLETIN No. 5.

A SUGAR-CANE LEAF-HOPPER
IN HAWAII

BY

D. L. VAN DINE,

ENTOMOLOGIST, HAWAII AGRICULTURAL EXPERIMENT STATION.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS.

U. S. Department of Agriculture.

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**HAWAII AGRICULTURAL EXPERIMENT STATION,
HONOLULU.**

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

STATION STAFF.

JARED G. SMITH, *Special Agent in Charge.*
D. L. VAN DINE, *Entomologist.*
EDMUND C. SHOREY, *Chemist.*
J. E. HIGGINS, *Horticulturist.*
J. B. ADAMS, *Foreman.*

LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, January 23, 1904.

SIR: I have the honor to transmit herewith for publication as Bulletin No. 5 of this station, a paper entitled A Sugar-Cane Leaf-Hopper in Hawaii, prepared under my direction by Mr. D. L. Van Dine, the station entomologist.

Very respectfully,

JARED G. SMITH,
Special Agent in Charge.

DR. A. C. TRUE,
*Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.*

Recommended for publication, with the concurrence of the Entomologist.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON, *Secretary of Agriculture*

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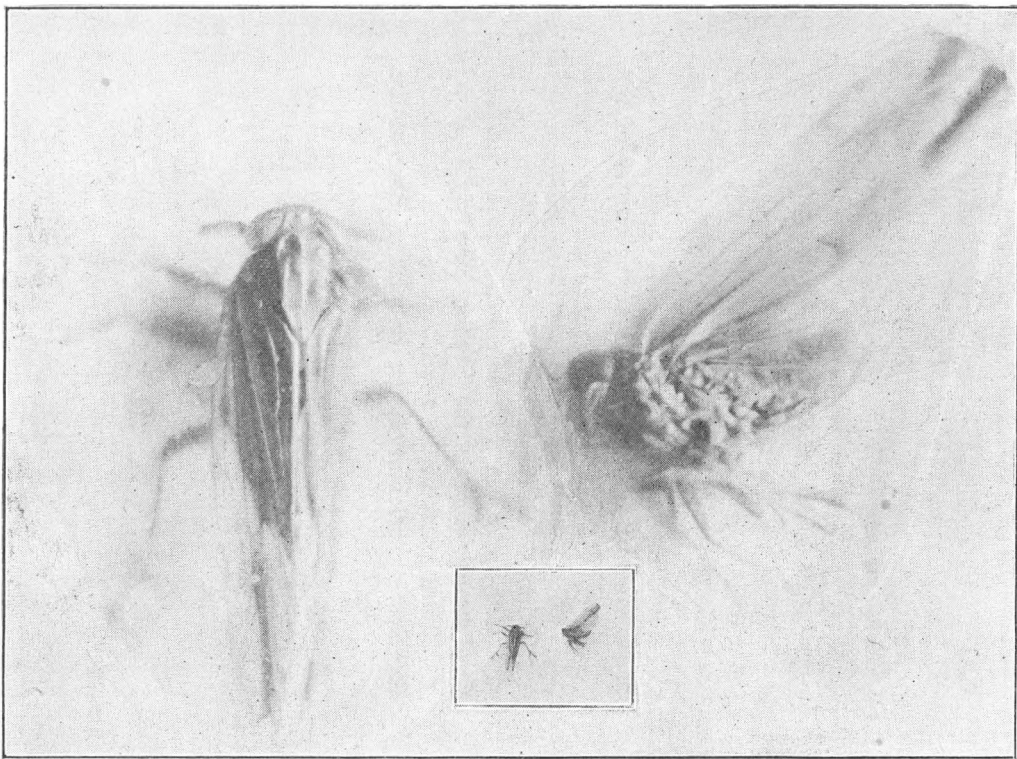


FIG 1.—Adult Leaf-Hoppers, greatly enlarged. Shown natural size in small figure below.*

*The illustrations in this Bulletin are original.

A SUGAR CANE LEAF-HOPPER IN HAWAII.

In February and March, 1903, a leaf-hopper appeared generally throughout the cane fields of Hawaii in numbers sufficient to prove a serious check to the growth of the cane. This is an hemipterous insect, belonging to the family Fulgoridae. Specimens were forwarded on May 11, 1903, to Dr. L. O. Howard,^a Washington, D. C., who replied under date of June 1 that it was a new species, *Perkinsiella saccharicida* Kirkaldy.

Some of the planters have confused the leaf-hopper of the cane with one of corn which, they inform the writer, has been here for the past fifteen or twenty years. The leaf-hopper of the corn is an altogether different species, *Dicranotropis maidis* Ashm., and confines its work mainly to the corn. The leaf-hopper of the cane is a recent introduction and probably came into the Islands in seed cane brought here from Queensland.^b Its distribution over the Islands, at first unnoticed by the planters, has become so widespread that the pest can be said to be found generally wherever cane is being grown. The main factor in the distribution of this pest is the habit of the gravid female in depositing her eggs beneath the epidermis of the internodes of the stalk in which position they may be transported from one country to another or from one locality to another in cane-cuttings for seed. In this condition the pest was no doubt introduced into these Islands. Other factors, however, present themselves in the local distribution. The leaf-hopper is an insect readily attracted by light, as their

^aThe writer is indebted to Dr. L. O. Howard, Entomologist of the United States Department of Agriculture and his assistants, Messrs. Heideman, Schwarz and Banks, for the determinations of the leaf-hoppers mentioned in this paper and the predaceous insects taken in company with the leaf-hopper in the cane fields.

^bMr. R. C. L. Perkins, the well-known English collector, in a paper published recently on the introduction of the sugar-cane leaf-hopper into Hawaii, its native home and natural enemies, says that "it can be stated most positively that the present leaf-hopper attack is due to a pest comparatively recently introduced into the islands and not by one of old standing, which has suddenly become injurious, as some are inclined to think." Mr. Perkins has spent the last ten years here as a collector and it seems probable that this species would not have escaped his notice had it occurred on any of the various grasses. Had the insect, on the other hand, occurred on the cane it would undoubtedly have been noticed by Prof. A. Koebele the Territorial entomologist who records it first as appearing at the Sugar Planters' Experiment Station, Honolulu, in the autumn of 1900 (Hawaiian Planters' Monthly. 1902. Vol. XXI. p. 21.)

occurrence about lamps at night in the mills and homes on the plantations testifies. Passengers and steamship officers of the inter-island steamers have frequently stated to the writer on inquiry that in many instances, especially at night, great numbers of the insects have come aboard in certain ports or when off-shore certain plantation districts. These adults have undoubtedly traveled in this manner from one locality to another and an uninfested district might easily have become infested by adults flying ashore from a passing steamer previously infested while stopping at or passing by an infested locality. Railway trains have been equally active in the spread of the insect on land.

The writer's attention was first called to the insect by Hon. H. P. Baldwin, August 12, 1902, on cane growing at Puunene, Maui. The general appearance of the cane was healthy and it did not appear to be suffering from the attack. The pest had been detected by the presence of a black, sooty covering on the lower leaves. This peculiar formation has come to be known as the "smut" of sugar cane. In reality it is a fungus growth which finds a medium for development in the "honey-dew" or transparent, sticky fluid excreted by the leaf-hopper. The lunas (foremen) referred to this excretion as "lasses" (molasses) and stated that they had seen "plenty" the previous season (1901). It is evident from this that the leaf-hopper had been in the cane fields for at least two or three years.

At the request of one of the managers, certain plantations in the districts of Kohala, Hamakua and Hilo on the Island of Hawaii, were visited during the months of May and June, 1903. Acknowledgments should be made here for the many

The general distribution of the pest in 1902 would indicate that it was introduced several years previously. The leaf-hopper is presumably a Queensland species since it has been identified as identical with a species found in that country on cane and described as distinct from any other leaf-hopper infesting cane in other countries.

The strongest argument in favor of the leaf-hopper being a recently introduced species is its rapid spread and immense increase in numbers, a known fact as regards recently introduced injurious insects elsewhere which have found conditions for their development more favorable than in the country from which they came. This unusual fecundity must not be attributed entirely to the absence of natural enemies which might have preyed on them in what has theoretically been decided to be their native home as some writers would assert. The climatic conditions and food supply may be more favorable and are certainly equally important factors. Moreover, the nervous stimulus accompanying a decided change in environment in the life of any animal, tending towards the perpetuation of the species, is felt in succeeding generations for several years if the conditions for development are favorable as regards adaptability to climate and food.

and conditions of growth of cane is most valuable and im- courtesies extended by the managers of the various planta- tions visited. The information thus gained on the cultivation portant in offering suggestions on methods of controlling the pest. Whatever the method of control, the scientific investi- gator cannot work independently of the practical planter and obtain successful results. It is necessary that both classes of workers be equally conversant with the habits and life- history of the pest and the cultivation of cane. Many of the failures in the methods of control proposed for insect pests are due, not to the planter and farmer being indifferent to the recommendations, but to the results obtained in the lab- oratory and the theories based entirely on scientific argument not being applicable to the practical conditions in the field.

Up to the present time, the sugar plantations have been particularly free from serious attacks of insect pests and dis- ease. Because of this the planters are little acquainted with the insect life to be found in their cane fields. The cane-borer (*Sphenophorus obscurus* Boisd.) has been the most destructive and for that reason the one most generally known. It is safe to say that the borer and the hopper will not be the only pests with which the planters will have to contend in the fu- ture. With the profits of the sugar industry decreasing it will be necessary to study more closely the various insect pests of the cane, and there is demand on the part of the planters for practical, untechnical information regarding them. The pres- ent paper is written with this fact in mind.

THE LIFE HISTORY OF THE LEAF-HOPPER.

The members of the order Hemiptera to which the leaf- hopper belongs, have an incomplete metamorphosis; that is, their life history from the egg to the adult stage is not di- vided into definite stages of development, as is, for example, that of the moths and butterflies. These latter insects, as we know, first appear as worm-like creatures and after passing an intermediate stage, remaining inactive within a cocoon, emerge as the adult, with legs, wings and a head distinctly separated from the body. During this development the habits vary greatly, as when the caterpillar disappears to pass the pupal stage or period of transformation beneath the surface of the ground. The feeding habits also vary, changing per- haps from a destructive insect, the caterpillar, feeding on the leaves of some particular plant, to a harmless insect, the adult moth or butterfly, feeding on the nectar of flowers.

The leaf-hopper, on the other hand, belongs to a class of insects which do not at any time in their life history undergo a complete change in form, structure, or habits. The young on hatching from the egg are like the parent insect in pos-

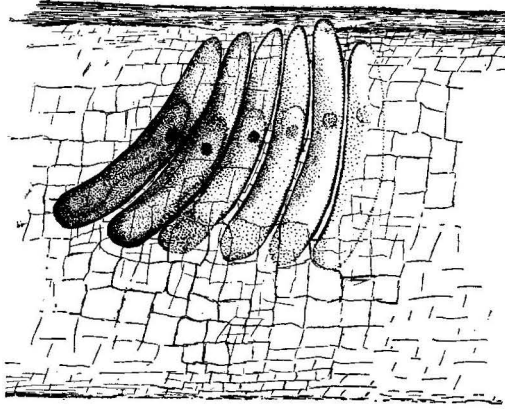


FIG. 2.—A longitudinal section of the mid-rib of a leaf showing a cluster of eggs embedded in the tissue. (Greatly enlarged.)

sessing legs, a distinct head and similar mouth-parts. Both the young and the adult leaf-hoppers occur on the cane but differ in that the young are smaller in size, wingless and sexually immature. As growth takes place, the "nymphs," (See figure 3.) or young wingless hoppers, gradually acquire the characteristics of the adult. Increase in size is provided for by shedding, from time to time, the outer, inelastic covering of the hard, shell-like, chitinous substance common to all insects. This peculiar operation is known as "moulting." The nymphal or larval period of development corresponds to the caterpillar stage of moths and butterflies.

The eggs of the leaf-hopper are deposited beneath the epidermis of the plant along the mid-rib of the leaves, in the internodes of the stalk, or, in young unstripped cane, in the leaf-sheath of the lower leaves. (See figure 2, showing a cluster of eggs embedded in the tissues of the mid-rib of the leaf.) The eggs are inserted in the leaf from both sides, usually from the inside, down next to the leaf-sheath. The place of incision is indicated at first by simply a whitish spot, a waxy covering over the opening made by the ovipositor of the female in depositing the eggs. The ovipositor of the female is a structure plainly visible on the lower side of the abdomen, attached to the body at the center behind the last pair of legs and extending backwards along the median line nearly to the

end. (See figure 4.) By aid of this apparatus the female pierces the epidermis of the cane plant and forms a cavity to receive the eggs. The number of eggs in each cavity va-

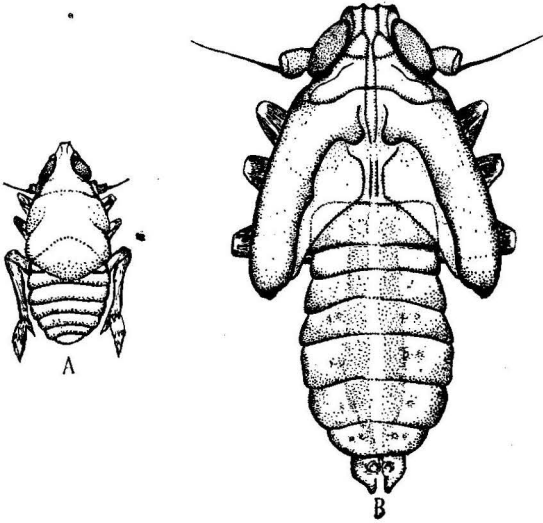


FIG 3.—Two nymphal stages, illustrating the developmental period of the leaf-hopper A, First stage; B, Fourth stage. (Greatly enlarged.)

ries, usually there are from four to six. One female is responsible for many of these clusters, as shown by the immense increase of succeeding generations. As the growth of the cane continues, new leaves appear above and the leaves infested with the eggs occupy a lower position on the stalk. By this time the egg-cavity is indicated by a reddish discoloration, a claret-colored spot well fitted to direct the observer's attention to the location of the eggs or the chamber they occupied if they are already hatched. As a symptom of a leaf-hopper attack these marks will be referred to as "egg-spots." (See figure 5.)

On issuing from the egg cavity or chamber, the young, newly-hatched hopper appears at first a small, long, slim creature, very light, almost transparent in color. During the process of hatching the tiny insects can be seen by the aid of a hand-lens, pushing or rather pulling, their way headfirst to the surface of the leaf or stalk. This operation occupies from eight to fifteen minutes, during which time they rest occasionally to unfold and dry their legs. When, after much wriggling and twisting, the insects become detached from their egg cases, they scatter at once over the plant to feed, congregating for the most part down within the sheaths of

the upper leaves during the daytime. After several hours the body becomes shortened and the outer covering on exposure to the air becomes darker in color. The habit of secluding themselves makes their presence inconspicuous to an ordinary observer, and unless especially sought for, they may become abundant in the field and remain undetected until after the result of their work becomes evident.

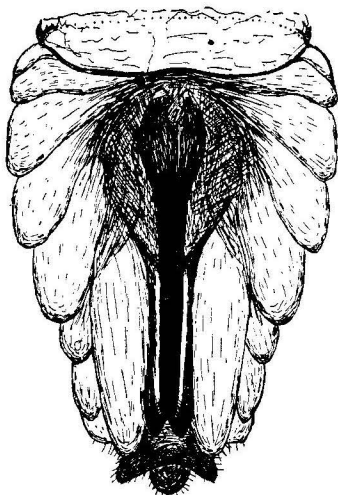


Fig. 4.--Ventral view of the abdomen of the female, showing position of the ovipositor.

Breeding experiments are now being carried on in the insectary of the Station (see figure 6) to determine definitely the life-cycle of this insect, the time passed in the egg-state and the length of the different periods between the moults or changes the insect undergoes before reaching maturity.^a

^aSince the above was written, careful observations have been made on the life-cycle of the leaf-hopper. Cane was grown in plots out of doors and in boxes in the insectary. The boxes, in the latter case, were enclosed in frames covered with wire netting.

The cane planted out of doors was put in the ground January 20, 1904. As the cane appeared above the ground and continued to grow, it was carefully examined from day to day for evidences of the presence of leaf-hoppers. The writer expected to find in the course of time the young nymphs since the seed-cane contained many egg-chambers. This is the supposed method by which the leaf-hopper has been so widely distributed over the Islands, that is, in the egg-state, beneath the epidermis of the cane cuttings transported for seed. That this was not the case in this instance was clearly shown since no young appeared. These observations do not dispute the fact, however, that the leaf-hopper is transported in cane cuttings for previous to planting, it is quite possible for the eggs to have hatched in some numbers and provided other cane is growing near, as is invariably the case on plantations, the insect would undoubtedly escape to the growing cane and continue in its development.

During the winter season, a short-winged or "brachypterous" form appeared. This variation of the wings was noted to a great extent by some of the managers of the plantations dur-

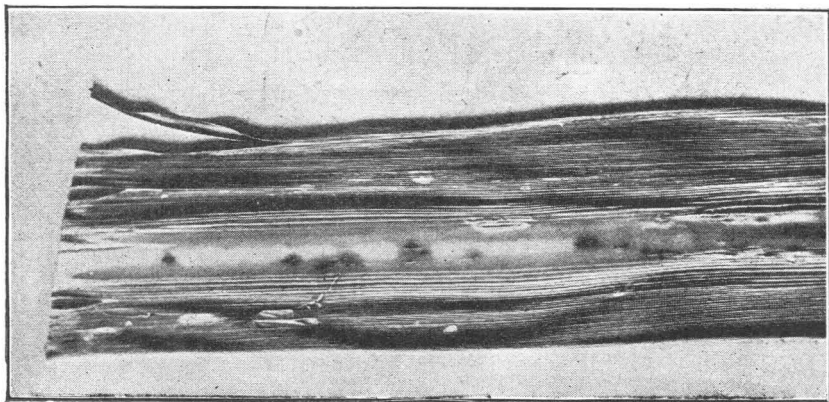


FIG. 5.—"Egg-spots" on the mid-rib of a leaf.

The first signs of the leaf-hopper on the cane were adults which appeared March 1. On this day six specimens were observed. The attack was clearly an invasion from without. On March 7 egg-spots were noted on the mid-ribs of some of the lower leaves. These typical markings were not at all evident and only careful search revealed their presence. The numbers of adults gradually increased. The nearest cane was growing a half-mile distant. The writer, from these observations, was led to inspect various plots of cane wherever found growing in isolated places. Invariably these patches of cane were found to be infested with leaf-hopper. The most interesting case was a single stool of cane growing in a dooryard about one and one-half miles from any other cane, so far as known. The writer has found the eggs in the mid-ribs of the leaves of sorghum and it would seem that the insect has adapted itself to other food plants such as sorghum and various grasses.

On March 15 some of the egg-spots had become a reddish tinge in color and this typical claret color became more pronounced from this date on. On March 26 the first eggs began to hatch, making the egg state 19 days in length. The adults from these nymphs appeared on May 2 thus making the five nymphal stages, or developmental period, 37 days in length. To sum up the outdoor observations: the egg state was 19 days in length, the nymphal state 37 days (averaging about 7 days for each stage), making the complete life-cycle a matter of 56 days. The temperature ranged from 58 degrees (F.) to 83 degrees with an average of about 72 degrees.

The cane planted in boxes in the insectary on January 22 was two and one-half feet high on March 21. On this day the cage was liberally stocked with adult female specimens collected from the cane out of doors. No egg laying occurred during the day but the following morning, March 22, many egg-spots were observed, the eggs having been laid either during the night or early morning. Eggs are, however, deposited during the day, since the writer has observed a female in the act of egg-laying at 9:30 A. M. and at another time one performing the same operation at 3:00 P. M. The eggs were deposited on the young cane in the breeding cage in the mid-ribs of the leaves, for the most part down near the sheath on the inside of the lower leaves and in the sheaths of the lower leaves from the outside. In the latter case the eggs were not placed in the tissue of the sheath but inserted through the leaf-sheath and laid between it and the internode of the stalk.

On April 5 the first nymphs began hatching from the eggs. It was a difficult matter to obtain the exact number of days necessary for the

ing March and April, and gave rise to the report that the insect could not migrate from one locality to another, since, having no wings, it could not fly. When the writer visited the cane fields later in the season, these short-winged forms

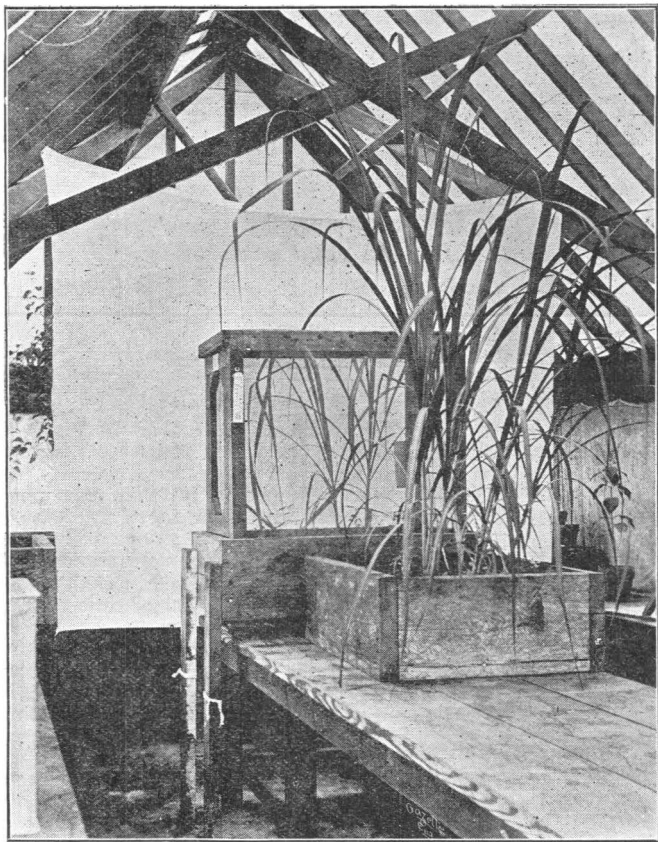


FIG 6.—Breeding-cage in the Station insectary

development of the different nymphal stages since the young hoppers varied greatly in the time of hatching, some not issuing from the egg-chamber until the sixteenth day, or April 7. The change to the second nymphal stage varied still more but assuming that the first specimens to hatch were first to reach maturity, the life-cycle can be fairly well made out. As stated in the out of doors observations, the nymphal period is made up of five distinct stages. The first nymphal stages are several days shorter than the later and range from four to nine days. The first adults appeared on May 9, making the nymphal period 34 days, and the entire life-cycle 48 days. This is eight days shorter than the developmental period out of doors, accounted for by the more favorable conditions, being mainly a difference in temperature. During this time the temperature in the insectary ranged from 63 degrees to 87 degrees with an average of about 77 degrees, the temperature out of doors being some five degrees lower. As small as this difference may seem, it is very marked in the

were the exception. Westwood, as early as 1840,^a mentions such a variation occurring in leaf-hoppers belonging to the genus *Delphax*, "the majority of which," he says, "in our English species, have the upper wings not covering more than half the abdomen, the terminal membrane being deficient as well as the hind wings. In certain seasons, however, especially hot ones, the wings are fully developed." The writer is of the opinion that a scarcity of the food supply would have quite as much to do with the production of a winged form as the temperature.

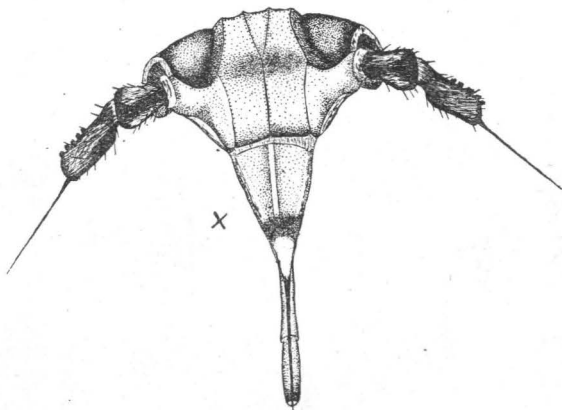


FIG 7.—Front view of the head of adult Leaf-Hopper showing "Beak" or proboscis. This structure when at rest is strongly recurved at x,—the proboscis lying along the lower median line of the thorax, between the first two pairs of legs. (Greatly enlarged.)

Ordinarily the leaf-hopper does not fly, but when disturbed, either moves off in an odd fashion to the other side of the plant or jumps. During the outbreak last season, however, there occurred in certain districts, regular migrations of this pest from one locality to another. Under date of June 4, 1903, the writer received the following reply from the man-

equable climate of these Islands. Such a difference in temperature is equal, generally speaking, to a difference of 3000 feet in altitude.

Mr. C. F. Eckart, Director of the Hawaiian Sugar Planters' Experiment Station, (Report. 1903. p. 78.) gives the length of the egg state much longer in cane cuttings. Infested stalks were cut in 8-inch lengths and placed in tightly covered boxes. No data is furnished as to when the eggs were deposited but young hoppers continued to hatch for 38 days after being placed in the boxes. The unusual length of time was due, no doubt, to the dried condition of the cuttings and it is quite certain that many of the embryos never developed at all. The fact that the eggs will hatch from cane cuttings after a period of at least 38 days is an important point to consider in shipping seed cane from one locality or country to another.

^aWestwood, *Modern Classification of Insects*, Vol. II, p. 431, 1840.

ager of one plantation in answer to a request for him to confirm a statement made by the manager of another plantation:

I can verify what Mr.....said, that for about two hours on Sunday night, April 26, the atmosphere was thick with "hoppers," same cloud of "hoppers" had extended for two miles as Mr..... happened to telephone to me on my return and stated that he found the same conditions at his place. It seemed to me that they were traveling with the prevailing wind, about southwest.



FIG 8.--Dusting-machine in use on plot of cane at the Station.

This is not the first instance that a leaf-hopper has seriously attacked cane. Westwood describes a species under the name of *Delphax saccharivora* as injurious to sugar cane in the West Indies in 1841.^a In regard to this species he says:

^aMag. Nat. Hist. Vol. VI, p. 407; and, Trans. Ent. Soc. Vol. I, app. pp. 28 and 70.

One species, having habits similar to the Aphids, is extremely injurious in the West Indian Islands from its attack on the sugar cane, which it often kills, from the vast numbers of the individuals with which the plants are infested.^b

The leaf-hopper of the corn is not a new species and it is interesting to compare the life-cycle of this species with that of the one infesting the cane. The corn leaf-hopper was first described from Florida by Mr. W. H. Ashmead under the name *Delphax maidis*, in an article in *Psyche*, 1890 (pp. 321-324). Mr. E. P. Van Duzee in 1897, referred Mr. Ashmead's species to the genus *Dicranotropis*. Mr. Ashmead states that the life-cycle occupies about one month during July, August and September. Mr. A. L. Quaintance in an article on the same species,^a published in 1898, found the life-cycle during the winter months was much longer than this and sums up the results of his breeding experiments with the statement that, "the egg state continued for seventeen days; the first nymphal state for eight days, the second five, the third nine, the fourth ten, and the fifth for eleven days, thus making the life-cycle sixty days." Mr. Quaintance says further: "This difference in time (between the life-cycle of the summer and winter broods) is no doubt due to the lower temperature, and well illustrates the effect of change of temperature on the development of insects."

Mr. Ashmead mentions a short-winged form occurring with the leaf-hopper of the corn.

THE INJURY TO THE CANE.

The piercing of the epidermis of the leaf by the ovipositor and later the rupturing of the tissue of the leaf on hatching, is the first injury to the plant from the leaf-hopper. The leaf itself is not only weakened, but the many openings in the leaf and stalk allow excessive evaporation to occur, which is a great drain on the vitality of the plant. Further, it is through these wounds that various diseases may gain entrance to the tissues of the plant, carried thither by the wind or on the bodies of the leaf-hoppers and other plant-feeding insects.

The most serious injury to the plant is caused by the young developing hopper in feeding. To understand how the insect secures its food and in doing so injures the plant, it is

^aFlorida Experiment Station. Bul. 45.

^bKruger records, besides the West Indian species mentioned above, two species infesting sugar cane in Java and Borneo, *Dicranotropis vastatrix* and *Eumetopina krugeri* and a third Javanese species, *Phenice maculosa*.

necessary to know the structure and function of the mouth-parts. Insects feeding on the external parts of plants are divided into two great classes, for convenience merely, according to the manner in which they feed, namely, biting insects and sucking insects.

The typical mouth-parts of insects of the biting type, that is, the appendages making up the parts of the mouth, are constructed in a jaw-like fashion for actually biting off and eating portions of the plant on which the insect is feeding. The other class, the sucking insects, possess mouth-parts, the appendages of which are differentiated into a beak or proboscis, forming not only an instrument to pierce the outer covering or epidermis of the plant, but also, being tubular in structure, an apparatus for sucking or drawing the sap from the tissues, leaving the part of the plant upon which the insect feeds still intact. The mouth-parts of the leaf-hopper belong to the sucking type (See figure 7) and the food consists not of the leaf itself but of the juices or "sap" contained in the tissues.

A further injury to the plant is due to the fungus accompanying the leaf-hopper attack. The presence of the pest has been in many cases first detected by the black discoloration on the lower leaves. The leaf-hopper is an insect which, like the plant-lice (Aphididae), excretes a sweet substance commonly known as "honey-dew." Certain fungi find this substance a medium for development and thus, when the pests occur in large numbers, proclaim the presence of the insects.

Leaves of cane infected with this fungus were sent to Dr. A. F. Woods, Pathologist and Physiologist of the United States Department of Agriculture, who determined the "smut" as a species of the genus *Sphaeronema*.^a This fungus

^aDr. Woods' letter, dated Washington, D. C., June 24, 1903, reads as follows:

Your letter accompanied by so-called smut of sugar-cane was received and referred to Dr. Erwin F. Smith, who reports that he has had the specimens examined in his laboratory with the following result:

"The sooty black covering of the leaves is made up of a closely septate brown mycelium and of innumerable pycnidia embedded in the epidermis of the leaf and provided with long necks. These pycnidia belong to the genus *Sphaeronema*. The inner tissues of the leaf are traversed by a fine white mycelium which in some places is becoming brown and closely septate, resulting in what appear to be internal chains of spores. This is probably what Massee calls *Trichosphaeria sacchari*. The appearance of the leaf corresponds to his description, and the bundles are reddened as he describes. The fungus probably enters the plant through wounds caused by insects. In one place what may be a young perithecium was found. This looks like Massee's figure of his perithecia. The pycnidia bear a strong resemblance to those of the sweet potato disease caused by *Sphaeronema* (*Geratocystis*) *fimbriata*. Went considers that Massee did

affects the plant mainly by preventing the assimilation of the elements taken up by the plant from the soil as food, or, in other words, retards the formation of sugar by cutting off the rays of direct sunlight. Still another fungus was taken on some of the irrigated plantations or in damp localities, occurring on the surface of the leaves, similar to the "smut" but white in color. This was determined by Dr. Woods as a species of the genus *Hypochmus*. These two superficial fungi must not be confused with the disease found in company with the smut but infecting the tissue of the leaf which Dr. Woods determines as *Trichosphaeria sacchari* of Masee or the disease of cane cuttings infecting seed cane and determined as *Thielaviopsis ethacetica* of Went. (See Press Bulletin No. 9 of this Station.)

All the fungi mentioned above belong to a class of so-called *imperfect* fungi. They are quite distinct from each other in appearance and infect different parts of the plant, yet their complete life-cycle has not in any case been fully worked out. In some phases of their development, the various forms resemble each other and further investigation may definitely show that some or all are merely different stages in the development of some one fungus disease as several authorities now believe. However, a very important point regarding these various fungi is generally admitted, namely, that plant-feeding insects, such as our cane-borer and leaf-hopper, are very active in the dissemination of these diseases. That is, they are carried from plant to plant by these pests, and through the wounds caused by them, the diseases gain an entrance to the tissues of the plant, with the exception of the disease of the cane cuttings used for seed, which may be further infected through the mechanical wounds caused by the cane knife.

SYMPTOMS OF THE LEAF-HOPPER ATTACK.

The formation of reddish spots along the mid-rib of the leaves is the first symptom of the leaf-hopper attack. These are the egg-spots, as has been explained, and indicate the location of the cavity constructed by the female for depositing her eggs.

not definitely establish the connection between the conidial stage and the perithecial stage of the fungi he describes. This fungus caused serious trouble in the West Indies when the diseased canes were left lying on the ground. Such canes should be removed from the field. It is impossible to tell with any certainty, but I am inclined to think that the dying-back of the canes mentioned in the letter may be due to this fungus."

The "smut" or black fungus growth in the honey-dew is another symptom. The honey-dew excreted by the insect is at first a transparent, sticky fluid, sweet to the taste, which was given off in such abundance in some instances, as to appear on the weeds and stones beneath the infested cane.

The appearance of the leaves is the most important symptom of the attack. The leaves on which the insects have been feeding have an unhealthy yellowish appearance, and when the pests occur in large numbers, are actually dried, not unlike in appearance, to the fully matured leaf that has dried up after having served its purpose. This premature death of the leaves is due to the fact, as stated above, that the food of the leaf-hopper consists of the sap or juice of the leaves. So long as the cane plant is able to produce new leaves, its life is not endangered, the injury being a check to growth, the seriousness depending on the numbers in which the hopper occurs. The result of the destruction of the leaves is seen on examining the joints of the stalk, they being shorter in length and smaller in diameter. Leaves prematurely ripened through the effects of the work of the leaf-hopper do not drop away from the stalk at the junction of the sheath but break and hang down at the junction of the leaf to the sheath, leaving the sheath still wrapped about the stalk. Leaves in such a condition remain green for some time attached to the sheath by simply the mid-rib, and an attempt to strip the cane results in leaving the sheath still adhering to the stalk. In the last stages of an attack, this continues until only the very young unfolded leaves remain, and the plant, lacking the vitality to send out new leaves, is in a dying condition. Many plants in such a condition will throw out lalas (a sprouting of the eyes) which continue to grow, but, being supported by or through the cane stalk, they render it worthless, unless the cane is cut soon and ground.

Another symptom which might be mentioned is the presence on the stalks of any great number of ants. Ants on the cane do not always indicate the presence of leaf-hoppers, but, attracted as they are by the honey-dew of the leaf-hopper, it would be well for the planters to investigate carefully the cane where the ants occur.

LIMITATIONS OF NATURAL ENEMIES AS A REMEDY.

The insect life in the cane fields is more abundant than the average planter is aware of. Aside from the borer and the hopper, there are several other forms more or less injurious,

many of no economic importance and still others of great benefit in that their food consists of the injurious species.

In discussing the control of any injurious insect, it is necessary to determine to what extent the pest is responsible for the failure of the crop, and likewise the dependence that can be placed upon natural conditions of climate and location, methods of cultivation and the resistance offered by the plant itself in keeping the pest from becoming a menace to the plant. The work of the natural enemies is also important. In some instances, however, the importance of their work has been overestimated.

However desirable natural enemies may be, the planter should not rest assured that their presence relieves him of the necessity of active and precautionary measures in fighting the pest. Even under normal conditions, the opposing forces of nature tend only to equalize each other. The condition of growth in the case of cultivated plants is an unnatural one, an artificial condition brought about by the interference of man with the balance in favor of the plant-feeding species of insects. The introduction of the predaceous and parasitic enemies is most desirable to equalize this unbalanced condition and this is the most that can be claimed for them. *The control of the pests rests on the efforts of the planters.*

The idea of controlling injurious insects by the introduction and dissemination of their enemies has been advanced by some entomologists. Briefly, the theory is this: every living creature has its natural enemies which prevent it from appearing in abnormal numbers, so that in the case of an injurious species, if its native home can be determined, the enemies which keep it in check could also be discovered. It is further believed that, by the introduction of these special enemies into a country where the insects which comprise their natural food occur, care being taken to eliminate the enemies of the parasitic or predaceous forms, they will exterminate the pests.

Contrary to this belief, the writer would point out the reasons why the planter should not trust to natural enemies alone and make no effort otherwise to protect his cane from the ravages of the leaf-hopper. The introduction of beneficial forms will but bring the numbers of these pests down to a more nearly normal ratio and thus render more successful the use of precautionary and active measures. It is obvious that the introduction of the special enemies of insect pests is an important line of work, especially in a country like Hawaii, whose injurious species are mainly introduced forms which,

under the many favorable conditions of development, lacking the natural checks of climate and special enemies of other countries, have increased in unusual numbers.

Certain facts that will limit the work of any species introduced to prey upon the leaf-hopper of the cane must be considered in discussing the question of natural enemies as a remedy. The limitations referred to are:

(1) In considering the conditions which keep an injurious insect under control in its native home, one must admit that the environment as regards climate and food-plants may have as much to do with this control as the natural enemies.

(2) The predaceous or parasitic enemy must be one which will recognize only the leaf-hopper as its food or host. Otherwise, the insect life in the cane fields is so abundant that one not confining itself to the leaf-hopper as its special food might prey alike without distinction on injurious and beneficial species already present.

(3) The predaceous insects and spiders at present in the cane fields are general feeders and will continue to feed on the insects in the fields, or on the introduced species.

(4) A special enemy of one particular pest does not protect the cane from other pests already in the fields or others likely to appear.

(5) The leaf-hopper throughout its life-cycle, except in the egg-state, is very active and not at the mercy of an enemy as is the stationary scale-insect or the dormant chrysalis or the more or less helpless larvae of other insects.

(6) Supposing that a parasite is successfully introduced, it will, if it confines its food entirely to the leaf-hopper, itself decrease in numbers as it decreases its food supply. The relief from the ravages of the pest would, under the most favorable circumstances, be spasmodic, since the planter would have to face the increase of the pest due to the decrease of its natural enemy until the natural enemy could again increase its numbers sufficient to overcome the pest.

(7) The amount of time spent in securing a natural enemy is a matter of several years. Such an investigation implies the determination of the native home of the pest, and then determining, collecting, introducing, breeding and disseminating its parasitic and predaceous enemies, and an interval for them to become established in sufficient numbers to check the pest. Aside from the time involved, such work is extremely expensive. In the meantime the crop is suffering and the damage, perhaps, beyond repair.

(8) The last and most important point is that a careful study of conditions in the cane fields where the work of the leaf-hopper is most in evidence, shows that the serious condition of the cane cannot be attributed entirely to the leaf-hopper.

On the plantations where serious outbreaks of the leaf-hopper occurred, careful investigations were made to discover conditions of season, location or methods of cultivation which might have been detrimental to the development of the cane. Some of the conditions upon which the last point is made are: (a) The season during which the attack was most serious, was not the growing season and in some localities the weather was most unfavorable for the growth of the cane. In one instance, for example, there were during one month twenty-four rainy days out of the thirty and since the temperature on a rainy day is some ten degrees lower than on a bright day, with the absence of sunshine to carry on the work of assimilation, a less vigorous growth of cane resulted; (b) the long duration of prevailing high winds; (c) unfavorable location of the field, for example, an undrained hollow or a washed ridge; (d) the rainy season being followed by a long period of dry weather without the means of irrigation, the cane lacking sufficient moisture to enable it to put forth the best growth. This point was demonstrated on an unirrigated plantation in the district of Kohala, Hawaii. A portion of a field was seriously attacked by the hopper during the month of September, 1903, after several months of dry weather. The manager of the plantation was able to run water into this portion of the field and irrigated the cane four times at intervals of about a week with the result that the cane, although showing the attack in the smallness of the joints grown during that time, recovered, and when the writer visited the field during the month of November, was not unlike other portions of the same field in appearance; (e) the presence of other pests, the cane-borer (*Sphenophorus obscurus*) and a leaf-roller (*Orniodes accepta*), in some cases these pests doing equally as much damage as the leaf-hopper; (f) the lack of thorough cultivation; and (g) the destruction of the cane on some of the makai fields by the salt spray.

NATURAL ENEMIES AT WORK IN THE CANE FIELDS.

One species of the lady-bird beetles (*Coccinella repanda*) was particularly abundant and a few specimens of another species (*Platyomus lividigaster*) were found. Both of these beneficial insects were introduced from Australia by Mr. Albert Koebele. Another predaceous species occurring generally throughout the

cane fields was a true plant bug, a representative of the family Pentatomidae (*Oechalia griseus*).

Two species of "aphis-lions" were found feeding to some extent on the very young hoppers. These were the larvae of the species *Chrysopa microphyta* and *Anomalochrysa hepatica*.

The most formidable enemies of the hopper are apparently several species of spiders. The writer observed two species feeding on the leaf-hoppers. They were *Tetragnatha mandibulata* and *Adrastidia nebulosa*.

In the forest mauka of Kohala, a fungus disease was observed infecting to a great extent, a species related to the leaf-hopper, commonly known as the "torpedo-fly" (*Siphanta acuta*) and belonging to the sub-family Flatidae. The fungus is an undescribed species of Isaria. This disease has been observed since infecting the leaf-hopper in the cane fields but efforts to disseminate it in the fields were unsuccessful. It is only in places where the atmosphere is moist and the insects occur in large numbers that the disease will spread. In places where it was observed, its attack on the leaf-hoppers was not sufficient to be of economic importance.

Mr. R. C. L. Perkins mentions^a a plant bug, *Zelus peregrinus*, as a destroyer of the leaf-hopper but, being a general feeder, attacking the lady-bird enemies of the scale-insects of our citrus trees, its development should not be encouraged. Mr. Perkins also describes a hymenopterous parasite of the leaf-hopper under the name, *Ecthrodelphax fairchildii*.

REMEDIES.

In taking up the question of a remedy for the leaf-hopper, it would be well for the planters to give up the idea of extermination, using the term in its correct sense. The question is one of control, keeping the pest down in numbers below the point at which it is able to check seriously the growth of the cane.

The term active measures implies going into the field and actually reducing the pest in numbers by direct means. The immense acreage would necessitate doing the work on a "wholesale" plan. The difficulty of getting in and through the cane fields after the cane gains any height, the prevailing slope of cane lands and the manner in which many of the fields are laid out for irrigation prevents taking a wheeled-outfit into the fields. Furthermore, the hoppers are very active and, since any insecti-

^aBul. 1. Div. of Ent., Board of Commissioners of Agriculture and Forestry. Territory of Hawaii. 1903.

cide used against this insect must kill by contact, the larger number would escape under the usual methods of treatment.

In the face of the above difficulties, the writer spent several weeks in the cane fields in a badly infested area attempting to devise some active measure of control. The work at that season of the year was greatly handicapped by the almost constant wind and frequent showers. In the first place a spray of kerosene emulsion was tried, it having been recommended as a remedy for leaf-hoppers in several instances. This substance was applied by means of knapsack-sprayers since the height of the cane and the interlacing of the stalks would not permit the use of a wheeled-outfit. While many of the hoppers were killed, the method was too slow and the force of the spray was not strong enough. In fact it was evident that the usual spray or mist was not efficient but that the emulsion needed to be applied in the shape of a finely divided stream with considerable force.

Lime was then applied as a dust, prepared by reducing fresh stone lime to a powder by solutions of copper sulphate and caustic soda. This was applied to areas badly infested with the black smut with the idea that it would serve the double purpose of fungicide and insecticide. This was a method found only applicable in the morning, on cloudy days or after showers for in the "heat" of sunny days the dust would not adhere to the dry surface of the leaves. In comparison to spraying, a much larger area can be covered by the dust method, doing away, as it does, with the great weight of water necessary in using a liquid spray. The hoppers appeared no less in numbers on the areas thus treated and the dust mixture must stand for the most part as a remedy for the fungus diseases. No doubt, however, many of the very young hoppers or those on the point of issuing from the egg-chamber would be arrested in their development.

The next method tried was collecting the hoppers from the cane by nets (the ordinary sweeping-net, used by entomologists in collecting supplied with a short handle, was taken as a pattern). Several were made and placed in the hands of a squad of Japanese women. With a little practice they were able to swing them successfully, going in a body through adjoining rows and by giving the cane stalks a sudden jar, sweeping the insects into the nets. At intervals buckets of water with a layer of coal-oil on the surface were placed. When the number of insects captured was sufficient to make it an awkward matter to swing the nets, they were dipped into the bucket to wet the insects, then opened and the major part of the lady-birds, assassin-bugs and aphidions liberated, the net turned inside out and the insects dumped

into the bucket. In the course of a week's time quantities of the hoppers were collected yet the numbers collected and the acreage covered were small indeed compared to the remaining portion of the infested area.

The stripping of the lower infested leaves was tried. The stalks were stripped as high as was possible without causing the plants to "bleed." Later reports were to the effect that the stripping was no doubt beneficial. The idea in stripping was not so much the effect it might have on the undeveloped embryos which the leaves might contain, as to render the conditions less suitable for the pest by removing a place of shelter and allowing to a greater degree the entrance of light and air, for it is in sheltered and shady places that the leaf-hopper works most unhindered^a.

The general conclusions of the experiments are that the use of sprays, dust, nets, or adhesive surfaces are not practical against a leaf-hopper attack in cane fields. On limited areas

^aSince the above was written, the Director of this Station, Mr. Jared G. Smith, has visited several plantations during a time when the leaf-hopper was epidemic. Mr. Smith's observations make it necessary to modify what has been written on the question of stripping. In a statement to the writer he says:

"On one of the plantations visited a field of about 300 acres of nearly ripe cane had been stripped at the beginning of winter, the season when growth practically ceases. During the winter the leaf-hopper became epidemic on this portion of the plantation. The hoppers not only made enormous numbers of punctures in the cane stalks, which had been stripped for their full length, but concentrated to such an extent on the leaves that the tops of the cane died or became very much weakened. Alcoholic and acetic fermentation ensued in the cane, simply because of the great number of wounds in the stalks, every joint having hundreds of punctures. If the cane had not been stripped the joints would have been largely protected from this injury and the cane would not have soured. The loss from this particular field was not due to any of the prevalent fungus diseases. Certainly the lesson in this instance was that cane should not be stripped at the beginning of winter.

One of the chief reasons for stripping cane is to prevent the formation of adventitious roots within the lower leaf-sheaths, a circumstance liable to occur with those varieties in which the stalks bend over and rest upon the ground for a considerable portion of their length, especially during wet seasons or in low-lying fields. Such root production would result in loss of sugar in the cane. Other reasons for stripping cane are the effect of direct sunlight on the cane, increasing the sugar-content or affecting the purity of the juice. If cane is stripped too high there is danger of infection of the stalks with the spores of parasitic fungi through the wounds made by tearing off the leaves which are still green. This source of fungus infection has been much emphasized by West Indian observers.

No hard and fast rule can be made as to whether cane should or should not be stripped. Stripping during the summer months, the growing season of the year, is undoubtedly beneficial. It may or may not produce beneficial results in the winter time. If the cane is to be harvested in late autumn or early winter it may safely be stripped even if the hopper is abundant, whereas, if the crop is not to be harvested until spring or early summer, the dead leaves left on the cane will protect the stalks from just such injury as in the case above cited."

which are badly infested, however, two remedies give promise of being of some value. In level fields where the cane has not attained a height of over three or four feet, a spray of kerosene emulsion delivered from a power-sprayer will no doubt reach and kill many of the insects. The force of the spray must be strong enough to carry well down into the leaves and strike the hoppers with sufficient force to wet them thoroughly. Prepare the emulsion by adding 5 gallons of oil (distillate 28% gravity) and $1\frac{1}{2}$ pounds of whale-oil soap to 5 gallons of boiling water. The soap should first be dissolved in the water before adding the distillate. Churn the mixture with a force pump until it has a creamy consistency and dilute with 15 to 20 parts of water before applying to the cane. The question of proper machinery should be well looked into before attempting to use this method. Since spraying is greatly limited and cannot be at all generally employed the details are not discussed in this paper.

As to the second remedy, the writer believes that it will pay to dust cane on which the "smut" or black fungus following the attack of the leaf-hopper is at all abundant. The dust is prepared by dissolving 25 pounds of copper sulphate (blue-stone) in sufficient water to slake thoroughly one barrel of fresh stone lime. The resulting powder should be well mixed and then sifted to remove all lumps. Thus dust can be applied to the cane by machines (See figure 8.) made expressly for the purpose, in the form of powder-guns. Several types are now on the market.

All trash after cutting the cane should be burned as soon as possible. This is advised for the destruction of other forms as well as the leaf-hopper. The immature forms in the trash and the adult insects in the field will be destroyed. Furthermore, the winged insects are readily attracted by lights and if the work of burning could be done at night, many of the winged forms of the neighboring fields would be drawn to the burning fields and destroyed.

Bonfires at night about fields and lighted torches in the fields were recommended as remedies in the early reports of Glover and Comstock for the leaf-hoppers of the grape-vine and wheat.^a The idea was that the insects attracted by the lights would be drawn into the fires and perish. Trap lanterns were also used for the same purpose. These remedies are not practical as methods of destroying the leaf-hopper of the cane, but much can be done by "burning off" during the night time.

On areas where the pest is really overcoming the cane, the

^aGlover. Rep. of the Ent. Rep. U. S. Dept. Agr. p. 85, 1871. Comstock. Comstock. Rep. of the Ent. Rep. of U. S. Dept. Agr. p. 191, 1879.

writer believes it would be better to cut the cane back and burn the infested field over, acting as it would, as a constant source of infection to the rest of the plantation, and allow a ratoon crop to grow.

PREVENTIVE METHODS.

In the main, dependence is placed on preventive methods, to control the pests of field crops. The planter will be able to control the leaf-hopper on the cane largely by precautionary measures. The greatest success in the control of injurious insects to field crops has been attained by methods of cultivation, taking into consideration the habits and life-history of the pest and the selection of resistant varieties. Since the cane is the sole crop and must be planted year after year on the same lands and also since certain portions of the plantations bear cane in the various stages of growth throughout the year, insuring a constant food supply to the pest, many of the precautionary measures practiced elsewhere are eliminated.

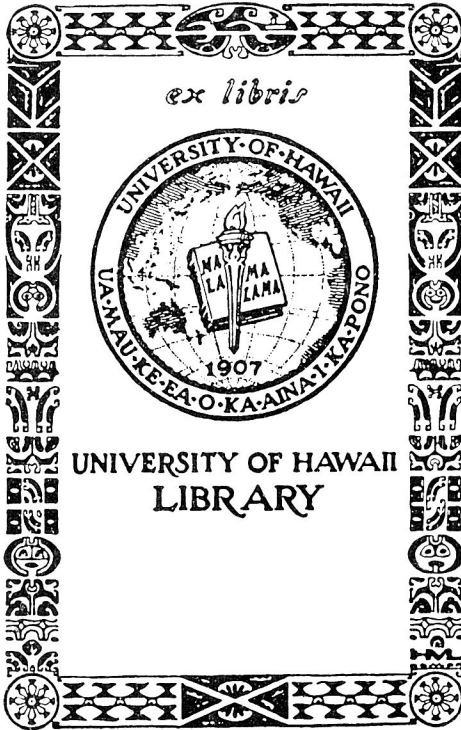
There is noticeable in general throughout the plantations a marked difference in the power of the different varieties to resist the attack of the leaf-hopper. While the same variety would vary in different localities as regards growth and resistance, still the difference between any two varieties remained constant. For example, of the common varieties grown, Yellow Caledonia and Demerara 117 were invariably the more resistant as compared to Rose Bamboo and Lahaina, and while the former were more seriously attacked in some localities than in others, wherever the opportunity offered itself for comparison with the latter, the Yellow Caledonia and Demerara 117 made the best showing. It is for the planter to decide whether or not the advantages of one variety over another is offset by the ravages of the leaf-hopper. If the work of the leaf-hopper is greater than the gain, in the absence of the leaf-hopper, in the yield between the two varieties, then it is policy to select the more resistant cane. Here certainly is an important line of investigation from the standpoint of plant-breeding. A variety test should be made at once to enable the planters to know the relative value of the varieties they already possess and the further determination and establishment of other resistant canes. In the establishment of a resistant variety of cane it is encouraging to remember that cane is planted from cuttings and not from seeds, and therefore will not be likely to revert to a non-resistant form.

Another point in preventive methods is the difference in the

power of healthy and unhealthy plants to withstand an insect attack or any injury, for that matter. All plants are surrounded by their various enemies, but when the plants are in a vigorous condition of growth, the pests cannot easily overcome them. Let a plant for any reason, such as deterioration of the plant itself, lack of proper available plant food in the soil, unfavorable location as regards climatic conditions or any of the various unfavorable conditions of growth, become weakened, and the work of destruction by any enemy that is present becomes evident. The vigor of the plant must be maintained by cultivation, irrigation, and the use of fertilizers.

It seems probable that many of the plantations will find it not only necessary but profitable to give certain of their cane lands a rest once in several years and plant an intermediate crop, either for the product itself or for green manure. In some cases, the check to the cane through the work of the leaf-hopper, combined with other sources of loss, more than covers the profit. It is, therefore, hardly wise to continue to plant such lands longer to cane since such fields simply tax the remaining portion of the plantation to that extent in making the crop as a whole profitable.

In conclusion, it can be said that the limitations of the natural enemies and the active measures are so many that the leaf-hopper cannot be controlled by these methods. A general effort on the part of the planters in selecting a variety resistant to the attack of the pest, a careful consideration of the various sources of loss in the cane fields, aside from the destructive work of the leaf-hopper, cultivation based on the life-history and habits of the insect, and the maintenance of the vigor of the plant by irrigation and the proper fertilizers along with thorough cultivation, will be the methods of control for this pest.



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