

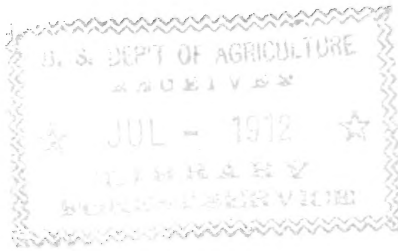


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THE RICE WATER-WEEVIL AND METHODS
FOR ITS CONTROL.

BY

E. S. TUCKER,
Entomological Assistant.

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BUREAU OF ENTOMOLOGY.

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THE RICE WATER-WEEVIL AND METHODS FOR ITS CONTROL.

(*Lissorhoptrus simplex* Say.)

By E. S. TUCKER,

Entomological Assistant.

ECONOMIC IMPORTANCE.

The most serious insect enemy of growing rice in the Southern States is the rice water-weevil (*Lissorhoptrus simplex* Say) (fig. 1). When in its larval stage, the insect is known to rice growers as the "rice root-maggot." The larvæ feed on the roots of rice plants, and the adult weevils cause some harm by feeding on rice leaves.

Owing to the extensive growing of rice in sections of Louisiana, Texas, and Arkansas within recent years, the weevil has found very favorable conditions in the rice fields for its multiplication in proportion to the increase of the acreage and to the number of years in which rice has been grown in any section. The development of definite rice-growing areas in these States has naturally resulted in particular centers of high infestation by the weevil. Rice growing has consequently been attended by great damage to the crops on account of the insect's attacks.

The amount of loss that is occasioned by the attacks is difficult to estimate, as the reduction of yield has been variously reckoned in different localities. Since all fields are not affected alike and different portions or spots of a field are apt to suffer the severest injuries, although the plants seldom fail outright, the growers differ much in their opinions of the extent of damage which they sustain, but all agree in the declaration that it is considerable. General statements of the shortage of production include a report by a grower at Beaumont, Tex., who placed his loss as low as 1 per cent; but the attacks in some fields at Stuttgart, Ark., have been severe enough to cut down the yield as much as 75 per cent.

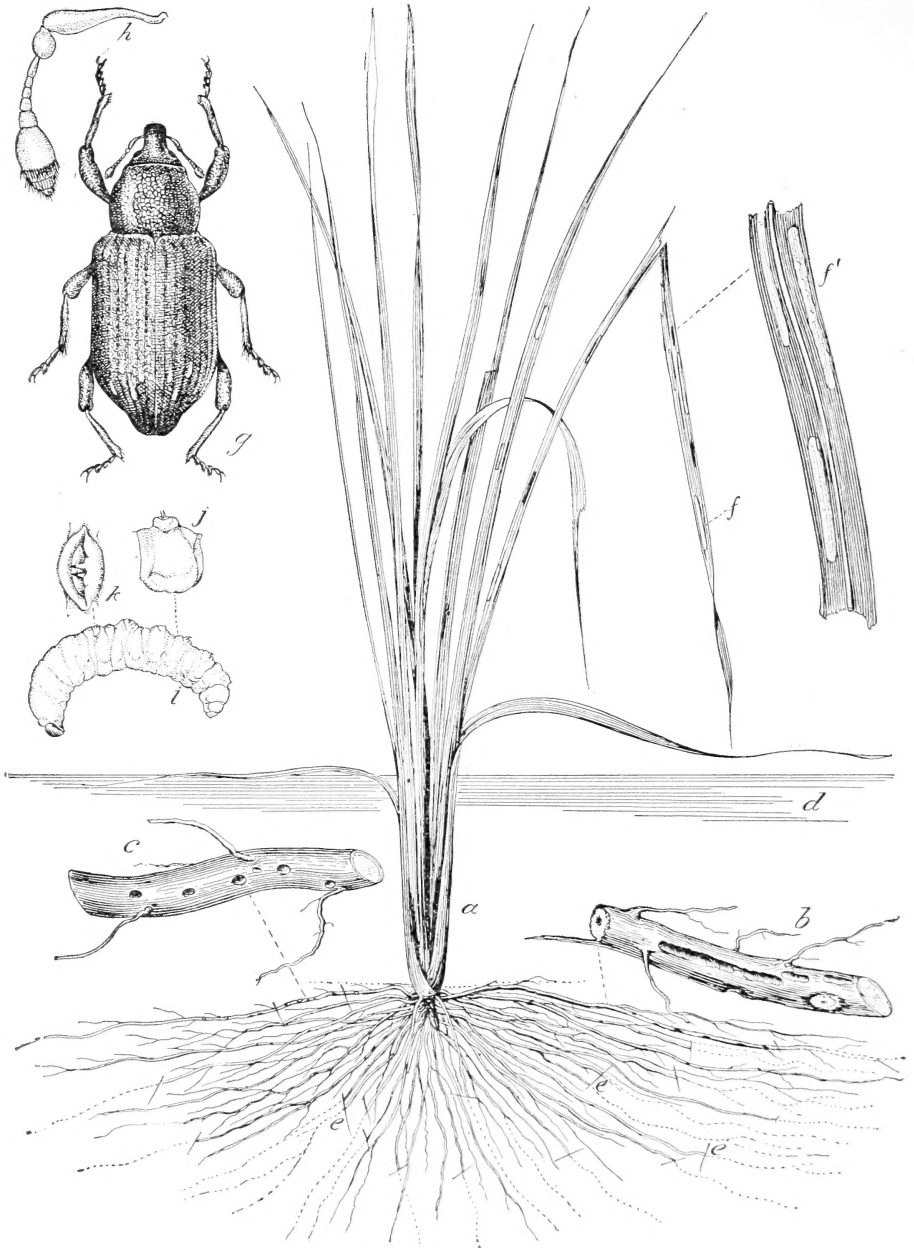


FIG. 1.—The rice water-weevil (*Lissorhoptrus simplex*): *a*, Rice plant showing injuries; *b*, larval scars on section of root; *c*, section of rootlet showing feeding scars; *d*, water line; *e*, *e*, roots severed by larvæ; *f*, injured leaf; *f'*, enlarged section of injured leaf; *g*, adult beetle, dorsal view, much enlarged; *h*, antenna of beetle, more enlarged; *i*, larva, side view, much enlarged; *j*, enlarged segment of larva, lateral view; *k*, dorsal structure of larva. (Original.)

The recent work of the bureau on the rice water-weevil was begun in 1910 by Mr. C. E. Hood, working under the direction of Mr. D. L. Van Dine. The present writer began work on the problem in 1911. In this circular many notes made by Mr. Hood are incorporated.

The object of this paper is to give as much practical information as is now available about the weevil and measures for its control in order that rice growers may make proper efforts in fighting the pest and secure larger crops. The cooperative facilities afforded by the Agricultural Experiment Station of Louisiana, through Prof. W. R. Dodson, director, in providing accommodations at the State Rice Station, Crowley, La., and allowing free use of the unpublished notes comprising a preliminary investigation of the rice water-weevil by Mr. Wilmon Newell, in 1909, deserve grateful acknowledgment.

HISTORICAL ACCOUNT AND DISTRIBUTION.

The weevil was originally described in 1831 as *Bagous simplex* by Thomas Say. It and another species of weevil were given the generic name of *Lissorhoptrus* by Dr. J. L. LeConte in 1876. LeConte and Horn have stated that the weevil commonly inhabits swampy places throughout the eastern part of the United States. Its northern range extends into the Lower Peninsula of Michigan, according to Hubbard and Schwarz, and Dury has recorded the species as being taken near Cincinnati, Ohio. It is also reported from New Jersey, Maryland, and the District of Columbia. Mr. E. A. Schwarz has concluded "that the genus *Lissorhoptrus* occurs all along the Atlantic coast (including the Gulf of Mexico), recurs along the Great Lakes, and is occasionally found inland."

As an injurious insect, the species first attracted the attention of rice farmers along the Savannah River in Georgia and South Carolina. In 1881 Dr. L. O. Howard visited a rice plantation known as "Proctor's," and owned by Col. John Screven, on the South Carolina side of the river, a short distance below Savannah, Ga., for the purpose of studying the insects affecting rice crops. An account of his observations, including notes on the rice water-weevil, was published in the report of the United States Commissioner of Agriculture for 1881 and 1882. But little advance has been made in further knowledge of rice-crop insects up to the present investigation.

DESCRIPTIONS OF STAGES.

The adult.—The mature insect is a small, dark-gray weevil (fig. 1, *g*). The technical description by Mr. E. A. Schwarz in the account above mentioned is here quoted:

Lissorhoptrus simplex.—Imago: Average length from tip of thorax, 3 mm. Oblong-oval, covered with large, dirt-colored scales, but usually entirely en-

veloped in an argillaceous coating, which renders scales and sculpture irrecognizable. Rostrum stout, as long as head and thorax, subcylindrical, densely rugosely punctulate, neither sulcate nor carinate; head densely punctulate. Thorax as long as wide, constricted anteriorly, lateral lobes well developed, sides moderately rounded, base truncate, a finely impressed median line, surface densely rugosely punctate, sides at middle with a shallow transverse impression. Elytra much wider at base than thorax and about twice as long; humeri oblique, strongly declivous at apex, punctate-striate, interstices wide, subconvex, 3d and 5th more prominent at declivity than the rest. Prosternum flattened, transversely impressed in front of coxæ; abdomen coarsely punctate. Tibiæ somewhat curved, armed with a strong terminal hook; tarsi narrow, third joint not emarginate; claws slender, approximate.

Very little difference exists between the sexes. The females usually have a slightly larger body than the males, and are often more distinctly marked with a black area on the back. The marks of coloration, however, show more plainly on live moistened specimens in the field than on dry examples either alive or dead. According to Mr. W. D. Pierce, a secondary sexual character is presented by the configuration of the scrobe on the beak. He has determined that the scrobe of the female is slightly curved, but in the male it is practically straight. These fine distinctions are difficult to make out with certainty on account of the natural curvature of the beak.

The pupa.—No example of the pupa fit for description has yet been obtained, as it is very soft and any slight pressure or touch that is exerted in attempting to remove one from the mud crushes or distorts it.

The egg.—All attempts to secure deposited eggs have afforded only partial results. For purposes of description dependence must at present be placed upon the appearance of eggs obtained by dissection of gravid female weevils. Mr. Wilmon Newell, in presenting a description based upon such observations, has stated that the egg is pure white, cylindrical and slightly curved in form, and has a length about five times the diameter. It is barely visible to the naked eye.

LIFE HISTORY.

SEMI-AQUATIC HABITS.

Water is an element in which the weevil delights. It swims readily on or beneath the surface, and it feeds, rests, and mates almost as frequently in the water as above it. To determine how long the adults can live under water, Mr. C. E. Hood conducted a test in which one weevil died after passing the first 24 hours of submersion, but two did not die until after being kept submerged for fully 96 hours. The weevil does not carry a bubble of air for breathing purposes when it goes below the surface, although tiny globules of air are apt to adhere to parts of the body. Without water, the insect can not breed. The eggs are probably deposited on roots under water or in mud, and the

larva, and doubtless also the pupa, require a bed of saturated earth in which to live. Wet conditions of soil with suitable vegetation appear to be necessary for the development of all the stages.

FOOD PLANTS.

The semiaquatic life of the insect demands that its proper food plants be adapted for growing in moist situations or entirely in water. The adult weevil itself is not disposed to feed on any plant unless the roots are at least partially covered with water or soft mud. In South Carolina Dr. Howard observed weevils feeding on "Sagittaria, Scirpus, Cyperus, Nymphæa, and Nuphar"—plants commonly known as arrowhead, bulrush, galingale, water lily, and spatter-dock. Besides these, he reported wild rice (*Zizania aquatica*) as well as cultivated rice (*Oryza sativa*). One specimen has been collected as a visitor on Baptisia at Victoria, Tex. All positive records of additional food plants refer entirely to grasses and they are the result of observations that were mostly made in Louisiana. Mr. Hood has reported some of the Louisiana grasses by the common names of "bull grass" and "nigger's wool," which grew at Crowley. "Hurrah grass" was recorded by Mr. D. L. Van Dine at Matagorda, Tex. Adult weevils fed on the leaves of these undetermined grasses and the larvæ were found on the roots of the first, which was identified by the writer as a Paspalum and was said to have been introduced into the country. "Bull grass" is a very common term in the section and refers to several species of grasses.

The occurrence of weevils on Walter's swale grass (*Paspalum membranaceum*) was first observed by Mr. Newell at Lake Arthur, La. While similar observations have been made by the writer at Crowley, La., and Pine Bluff, Ark., the finding of larvæ on the roots of the grass at Crowley presented complete evidence of the true host relationship of the plant. This fact, however, may have been discovered by Mr. Newell two years previously at the same place where he found larvæ infesting the roots of a stocky Paspalum, which he was inclined to regard as another species.

Also during the season of 1911, at Crowley, La., the writer found two other species of grass which attracted the weevils from the nearest rice plants. One of these was Bermuda grass (*Capriola dactylon*). It grew on a levee in a rice field which had become partly overflowed with the flood water. As an attempt had been made to grow it on the land previous to the rice crop, its occurrence under flooded conditions was exceptional, and no larvæ were found attacking the roots. It can not be considered as a proper host plant. In the other case, a bunch of "water crab grass," undoubtedly a species of *Syntherisma*, was making a desperate struggle for existence

within a flooded rice field. Having evidently started into growth before the field became irrigated, this crab grass was able to live in a depth of about 6 inches of water. Not only were the leaves severely fed upon by weevils, but the roots were attacked by larvæ.

APPEARANCE OF ADULTS IN RICE FIELDS.

Since the growing of rice offers special inducements for the breeding of the weevil, due to the attraction of the plants and the wet conditions which they demand for growth, rice has become the favorite food plant of the insect. Directly after the rice fields are flooded the weevils appear and commence feeding on the leaves of the young plants. In southern Louisiana, where much of the water is supplied by canals, the irrigation of rice fields usually begins in the first week of May, but the time of turning on water in different fields is often later, the flooding sometimes not being done until in July to accord with late planting. Where water is pumped onto the fields, a steady flow must be maintained for several days before any large area of land can be inundated. The flooding of fields in Arkansas is not generally effected earlier than the middle of June.

By following the application of water in every field the weevils gather most numerously on plants that stand in the depressions and lower portions having the deepest flood. Mr. Hood has counted as many as 18 weevils on a stool and 12 on a single plant. An average of at least 1 weevil to every 5 or 6 plants in one field has been reckoned by Mr. Newell. Some inclination to avoid direct sunlight during days of hot weather is shown by the weevils, as they seem to prefer positions in the shade of the plants and under the surface of the water.

They are rather sluggish except when swimming and are disposed to feign death if taken in the hand. They show no inclination to fly during the day and even refuse to expand the wings on being tossed into the air. Passage between separate plants is accomplished in the daytime by swimming. That they can fly for long distances, however, is clearly proven by their attraction to artificial lights at night. This propensity will be more fully discussed with reference to methods of control. Invasion of fields must therefore be consummated at night.

NATURE OF ATTACKS BY ADULTS.

Rice is attacked in the same manner as other similar host plants and the effects of the feeding by the adults are soon manifested by the appearance of scars on the leaves. (Fig. 1, *f*.) In the act of feeding, the weevil braces its body firmly on the upper side of a leaf, and moving slowly forward in a longitudinal direction either up or down the blade, it chews out the epidermis and produces a scar, leaving

the underside uneaten. These scars are very narrow, being in fact no wider than the spread of the mandibles, but they vary in length from a small fraction of an inch to more than 2 inches, depending on the time in which the insect engages in feeding. When the thin underside dries within the scar, it splits and forms an open groove throughout the injured space. The leaves suffer no serious ill effects from being fed upon unless the scars become numerous enough to cause wilting and dying. Adults prefer tender young plants rather than the coarser strong growth.

MATING AND OVIPOSITION.

Throughout the period in which the weevils remain in evidence, mating takes place on nearly all occasions when a male and female happen to meet, and this usually occurs on a leaf. The gravid females crawl down the stems of the plants and evidently deposit their eggs singly in a puncture that is first gnawed in a root. Mr. Newell has mentioned that he has seen adult weevils which he believed to be females make punctures on the stems below the water line. Mr. Hood and the writer have watched the operations of females when they apparently undertook to oviposit on rice roots within glass tubes. Each weevil thus observed deliberately sought out a place on a root and ate into it for about a minute. Then she reversed her body, gripped tightly, and pressed the tip of the abdomen over the hole which she had eaten out. Mr. Hood has recorded that he saw the ovipositor in the form of a brown tubular organ inserted into the hole. In this case the weevil remained in position without any apparent movement for 50 seconds before the ovipositor was withdrawn. The writer has not been able to see the ovipositor extended nor to detect an egg with certainty. The weevil may climb up above the water after each operation and rest for a long or short period, or continue her actions among the roots for a while. One weevil stayed among the roots for 45 minutes.

The device that was designed and used by the writer for observing the method of oviposition by the weevils is illustrated in figure 2. In its construction a long lamp chimney was placed upright in a saucer and cemented at the base with plaster of Paris. A wire support with the top bent into a loop of the proper size for steadying a closed-bottom glass tube, one with an inch diameter being used to hold the roots of a young rice plant in water, was first placed in the center of the saucer. The lower end of the support was also bent in a spiral to secure firmness after being set in the plaster. By means of a string tied to the upper part of the tube, it could be lowered through the top of the chimney into a standing position within the wire loop and also removed to permit close inspection of roots and insects inside of it whenever desired.

Mr. Hood has stated that the larvæ are first found in the rice fields from one to three weeks after the turning on of the water, the

time of their inception varying with the weather. Hot weather accelerates their development.

The young larvæ, which have doubtless hatched from eggs laid in the roots, begin to feed on them, and in course of time as the larvæ increase in size they devour or sever large portions of the root system. They have been known to eat holes in large rice roots and burrow into them.

Mr. W. D. Pierce, at Beaumont, Tex., in 1904, found vigorous larvæ consuming the entire interior of the roots. Figure 1,

c, gives a representation of six feeding holes made at a distance not more than one-fourth of an inch apart as Mr. Hood viewed them.

The common methods of attack result in a pruning of the roots, after which the severed portions rot and the remaining parts are further marred with feeding scars.

At this stage the hold of the plant upon the soil is greatly weakened and it can be pulled from the ground with ease. In some instances on record the root systems were entirely destroyed and the rice

plants floated in the water.

The injuries done by the larvæ first cause the leaves of the rice plants to turn a pale yellow and droop, the lower blades often resting on the water. With

severe attacks some of the leaves may die. These effects in the fields become most pronounced on plants growing in depressions and low portions of the land into which the water first flowed and where it

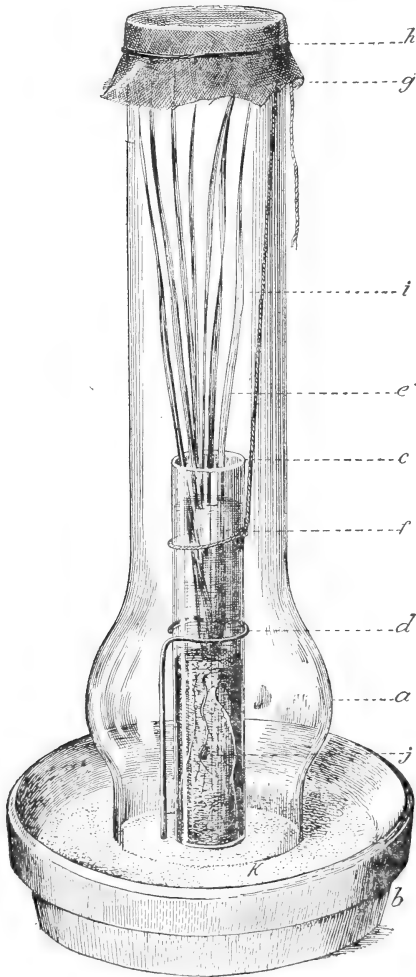


FIG. 2.—Lamp-chimney cage for rearing and observing the rice water-weevil: *a*, Glass lamp chimney; *b*, vessel containing plaster of Paris; *c*, glass tube; *d*, wire support; *e*, rice plant; *f*, string lift; *g*, gauze; *h*, rubber band; *i*, *j*, beetles feeding. (Original.)

stands deepest. As previously mentioned, such places are most attractive to the adults. Where the adults occur most numerous the larvæ must be expected to follow in great number. In consequence the severity of the larval infestations is shown by a yellow cast of the leaves extending in broad streaks along dead furrows, while spots and areas of yellowish plants also become visibly apparent within the hollows and sinks of the land. These signs of injury have appeared in fields after 20 days of flooding, but ordinarily the larvæ do not become numerous enough to cause much damage until the water has stood for at least a month.

If many of the roots are cut off from a plant (fig. 1, *e*), its growth is stunted, but as the growing rice plant possesses a strong vital power new roots are put out to replace the ones destroyed, and on the cessation of attacks the injured plant revives, or is said to "recover," and makes a belated growth, usually resulting in late heading. Much of the unequal growth of the plants in the fields, as well as the irregular maturity of heads, is accountable to the detrimental effects of the larval attacks. Harvesting must necessarily be delayed until all the heads are ripe, thus involving the risk of loss to the normal yield from storms or other causes.

Furthermore, the attacks on the roots of tender young plants prevent proper stooling or production of stems. In comparison with normal plants, often less than half as many stems grow from a stool that has suffered damage. Shortage of heads is therefore caused by the failure of badly injured plants to produce a full quota of stems. The fact that the larvæ are largely responsible for a great deficiency of yield in this respect will impress a comprehension of the amount of loss caused by the insect.

DEVELOPMENT OF STAGES.

The length of time required for the development of the weevil from a freshly laid egg has been estimated by Mr. Hood to be about 10 weeks. Judging from the first occurrence of larvæ in fields after 1 to 3 weeks of flooding, a period not to exceed 10 days would probably be ample time for an egg to hatch subsequent to deposition. Development is hastened with the advance of hot weather when the water and soil become warm. Usually not until about six or seven weeks after flooding do many of the larvæ attain full growth and appear ready for pupation, although pupæ have been found in a field that at the time had been irrigated for only five weeks. In preparation for the pupal stage the larva forms a cell in the mud among the roots or at the tip of one, and Mr. Hood has asserted that the pupa passes two or three weeks before it matures and the emergence of the adult takes place.

With the aim of working out the details of development of the larval and pupal stages, a number of larvæ were placed on the roots of young rice plants, each of which was set in water within a glass tube, the tubes being simply stood in a holder. Attempts to carry through the development of pupæ from larvæ when subjected to constant exposure to light proved only partially successful, but better progress, although still lacking completeness, was made after shielding the tubes from light and supplying a small amount of earth with the roots and water.

SEASONAL HISTORY AND GENERATIONS.

Adults as well as partially and full grown larvæ, and also without doubt the pupæ, occur in many fields up to the time of draining for harvest. With late crops in the coast region, however, and in the fields of Arkansas on account of the difference of the season in that State, the number of weevils in all these stages diminishes about the time when the plants begin to head in the latter part of August. Weevils found in fields after the drawing off of water to permit harvesting are apt to be freshly emerged individuals of a new generation. From a collection of infested roots obtained by Mr. Pierce at Beaumont, Tex., June 28, 1904, adults emerged as early as July 2 following. In case such early emerged weevils breed at once, they have a chance to produce a second generation in a season, provided they find late flooded fields or suitable water holes. At Stuttgart, Ark., on September 12, Mr. Hood found roots of rice infested by a few larvæ which he regarded as representatives of a second generation. The last larva found by the writer during his stay at Crowley, La., was taken September 25. While the weevils that emerge in July possibly lay eggs for a second generation, the species is principally propagated in one yearly generation.

In the spring, before many of the rice fields were flooded, Mr. Hood collected adults on grasses and red rice growing in ditches and other places containing water. Since the weevils have not been known to breed in such places until the soil and water become sufficiently warm, at which time the flooding of rice fields is well under way, the deduction is made that low temperatures up to this time exert a restrictive influence upon breeding.

Examination of roots of red rice and other plants growing in a constantly flooded ditch at Crowley, La., on October 3, failed to disclose any evidences of infestation at the time. These results show conclusively that the weevil does not breed at this time of year even in most favorable situations. Not only were the adults absent, but the lack of feeding scars on the leaves denoted that they had not visited there for some time.

The fact that adults live throughout the greater part of the season has been demonstrated several times. In an experiment with specimens collected at Mackay, Tex., April 5, 1904, Mr. W. W. Yothers succeeded in keeping the weevils alive by furnishing grass for food until after the middle of July. Weevils confined on rice plants by Mr. Hood at Crowley, La., July 18, lived later than the middle of September, and the writer has made a corresponding record covering a period from July 11 to September 21.

The common absence if not scarcity of fresh signs of feeding by adults late in the season or at the time when the new generation of weevils is expected to emerge throws much doubt on the question of their taking any food then. At least they do not remain long on the plants, and the few feeding scars that may appear to have originated at the time are likely produced by lingering adults of the old generation. A yearly overlapping of generations in the adult stage evidently occurs. Few specimens that might be regarded as freshly emerged weevils have been found in the fields. These were taken by Mr. Hood, hiding in the cracks of the ground after the water had been drained from the field for harvesting. Possibly some of these weevils stray to electric lights at night, my last capture of a weevil being made on the night of September 20. If a new generation of weevils occurs no evidence of it has been found. The question is, What becomes of them until they go into hibernation?

HIBERNATION.¹

During the fall and winter of 1910 Mr. Hood made examinations of various places which might serve as hibernating quarters. The materials examined included rice stubble, loose dirt in the fields, strawstacks (both old and new), grass and other vegetable matter along levees, and Spanish moss. No weevils were found hibernating except in the Spanish moss, which, however, afforded an excellent shelter, as the following tabulated observations made at Crowley, La., will show:

Observations on the places of hibernation of the rice water-weevil.

| Date of examination. | Moss examined. | Distance from nearest rice field. | Height above ground. | Number of weevils found. | Estimated number of weevils per ton of moss. |
|----------------------|----------------|-----------------------------------|----------------------|--------------------------|--|
| 1910. | | | | | |
| | <i>Pounds.</i> | <i>Mile.</i> | <i>Feet.</i> | | |
| Oct. 26..... | 1 | (²) | 6 | 18 | 36,000 |
| Nov. 19..... | 1½ | 0.25 | 10 | 21 | 28,000 |
| Nov. 28..... | 1½ | .38 | 6 | 4 | 4,920 |
| Nov. 30..... | 1½ | .50 | 6 | 1 | 1,454 |
| Dec. 1..... | 1½ | .50 | 6 | 2 | 2,666 |
| Dec. 2..... | 1½ | .25 | 6 | 45 | 60,000 |
| Dec. 5..... | 1½ | .25 | 6 | 28 | 34,460 |

¹ With the exception of a few remarks, all of the notes on hibernation of the weevils must be credited to Mr. Hood, who has made the most extensive investigations in regard to the subject.

² 300 yards (0.17 mile).

As indicated by the preceding table, several thousand weevils may hibernate in the moss on a single tree. The appearance of large numbers of weevils in rice fields when they are first flooded has led to the opinion that the pest completes one generation on host plants other than rice before this time. But as already pointed out, no evidence has been secured that will sustain this view. Abundance of the weevils is probably due to their successful survival through the winter and emergence from hibernation.

One reference in literature mentions the occurrence of adults "in wintertime under old leaves and other shelter in drier places near the swamps." The finding of one adult in litter beneath rich stubble is recorded by Mr. D. L. Van Dine as the result of searching for half of a day at Stewart, Tex., on October 28, 1909. Entrance into hibernation is probably not begun much before the time when the nights are cold enough for frost. Not a single weevil could be found by the writer in a collection of Spanish moss obtained on September 29, at Crowley, La., and in the preceding spring after the first weevils appeared Mr. Hood was unable to find any specimens remaining in the moss.

NATURAL ENEMIES.

Besides birds no enemy is known to feed on the mature weevils, although the snakes and frogs which frequent the fields probably do so. Bird droppings found by Mr. Hood in a rice field at Stuttgart, Ark., on September 12 consisted largely of insect remains, those of the rice water-weevil being the most abundant. However, two perfect specimens of the weevil were removed from the droppings and one was found to be alive. According to records in the Biological Survey, this weevil is eaten by the long-billed marsh wren (*Telmatorhynchus palustris*) and the mallard duck (*Anas platyrhynchos*).

Owing to their concealment in mud the larva and pupa are secure from enemies. When infested roots are pulled for examination and larvæ are washed out any minnows that happen to be present in the water will greedily snap the floating bodies. Predaceous larvæ of water beetles, which also abound in flooded fields, struggle with one another for possession of a weevil larva. If these predators and the several kinds of rapacious water bugs were adapted for burrowing in the mud and reaching the rice roots, they would be very efficient destroyers of both weevil larvæ and pupæ. But their habit of hunting in the open spaces of water renders them of little or no service against the weevil.

METHODS OF CONTROL.

DRAINING OF THE FIELDS.

As pointed out in the study of the life history, the existence of the larvæ and likewise the pupæ depends upon a saturation of the soil.

If the soil dries out after the larvæ have made an advance in growth, they soon die. The practice of draining fields and allowing them to dry enough to cause the death of the larvæ was first proposed in 1881 by Col. John Screven, a rice planter in South Carolina, and was indorsed by Dr. Howard after his investigation in the field in 1881. Some of the rice growers in Louisiana and Texas have reported good results from periods of draining, while others have claimed that the plants suffered more from being deprived of water than from attacks. Many growers therefore advocate deep flooding of fields as the proper treatment of rice when infested by the weevil larvæ.

Different results of draining are mainly accountable to the extent of damage done by the larvæ at the time of releasing the water. When the roots have been but slightly or not yet severely attacked, draining seems to result very effectively in most cases by the reduction of the number of larvæ to a minimum. Effectiveness depends on the length of time that plants can stand without water and not suffer from the want of it. Plants that have a fair hold of roots show no ill effects of drying spells lasting from 5 to 10 days without rain. In case of heavy rain, drying should be carried on for some days longer or until the surface of the ground forms a dry crust and begins to crack. This stage of drying has been found very effective in causing the death of larvæ, and the ground has still retained sufficient moisture below the surface to sustain the plants that possessed a large proportion of roots.

On the other hand, when roots have become severely pruned, the plants are unable to endure draining without being further impaired. Instead, they need a plentiful supply of water in order that new roots can be put out and growth resumed. The value of draining is dependent upon the enforcement of the practice at the proper time, which the grower can easily determine by making examinations of the roots. Many growers object to draining on account of the waste of water and the risk or difficulty of getting fields promptly flooded again. If fields were so arranged that water could be turned from one to another in succession or from early to late plantings, most of the water could be utilized and the saving in the cost of pumping, where this means of supply is employed, would be an item of consideration. Other benefits arising from changes of water will be mentioned later. Continuance of flooding to enable plants to overcome injury by larvæ, instead of taking steps to destroy the weevils, will, as Mr. Newell has inferred, probably lead to a regular increase of the number of weevils until the point is reached where the insect will make profitable rice culture impossible. Constant or extra flooding does not in the least inconvenience the larvæ, but makes conditions even more favorable for them. Being the most practical method of controlling the weevils, draining of fields is therefore highly important.

RESULTS OF DRAINING.

Conclusive observations upon tests of draining conducted by the writer or under his instructions during the season of 1911 are presented in the following statements.

At Crowley, La., on June 9, a rice grower drained some parts of his field of early planted Honduras rice in which fully one-fifth of the plants, then at a height of 15 to 18 inches, showed yellow blades. The roots had been rather severely pruned, but enough remained together with newly grown ones to permit draining with safety. As many as six and seven larvæ infested the roots of a stool. Reflooding was effected June 19, after a period of drying which had lasted nearly 10 days. Quite a noticeable difference existed between the drained and undrained rice on July 21. The plants in the drained areas had nearly all headed out uniformly, while most of the undrained rice was behind in growth, either not having headed or having heads just formed and blooming. Regarding recovery, the owner said that the plants which grew in the fresh water after reflooding soon lost their yellow color and took on a vigorous growth of healthy green, but in the undrained parts with standing water the plants recovered much more slowly. At harvest time the owner estimated his best yield on land that had been drained to check the weevil larvæ.

In the field of another grower, however, results were not so successful. These small young plants were not injured badly and showed only incipient spots and streaks of weak yellow color. This was a variety of Japan rice. The field was drained May 29 and reflooded June 8, giving a drying of 10 days. One week after reflooding the plants had taken on a fresh green color, and the infestation of the most injured roots had been reduced to a minimum, as shown by the nearly normal growth. Owing evidently to a second infestation, during which no draining was done, an irregular belated growth was displayed at heading time. Whether the outcome might have been worse without any draining can only be surmised.

Acting under a cooperative agreement, Mr. C. G. Haskell reported some very important results of his examinations at Almyra, Ark. On draining a field July 20 he found 25 larvæ on the roots of 25 stools. On flooding the field July 28 he found only two larvæ on the same number of roots. The result was accomplished by eight days of draining and drying. A stool usually produced five stalks or stems. By calculating percentages of infestation according to the number of stalks the draining must have reduced the proportion of larvæ from 20 per cent to 1.6 per cent.

Again, on draining a field July 25 Mr. Haskell found 50 larvæ on the roots of 25 stools, but on reflooding the field July 31 he found no more than 9 larvæ per 25 stools. The draining and drying therefore

lasted six days, and calculating on a basis of five stalks to a stool the infestation was reduced from 40 to 7.2 per cent. The writer's own examination of this rice on August 1, the second day of reflooding, gave substantial evidence of the reduction of larvæ in corresponding numbers, the count resulting in 3 larvæ on the roots of 40 stalks.

At Pine Bluff, Ark., on August 5 the writer made examinations in a rice field that had been drained for five days. On the roots of 105 stalks only nine larvæ were found alive. The infestation therefore amounted to approximately 9 per cent. The owner stated that before draining two and three larvæ occurred on a stool. Calculating five stalks per stool, the infestation then could not have been less than $33\frac{1}{3}$ per cent. In some places the ground was still saturated, but most of it was stiff mud. That the draining really caused a reduction in the number of larvæ by death was evidenced by the finding of two dead ones, and some of the live ones seemed weak as if about ready to die. Not many roots were badly cut and the draining began at an opportune time. The pumping of water on this field was resumed August 8, but it was not wholly flooded until a few days later. The drying covered seven days at least. No rain fell during this time, and the ground had begun to crack from drying. The results were considered very beneficial, as the larvæ caused no further trouble and the rice headed out splendidly.

EFFECTS OF RUNNING WATER.

Direct observations, as well as the testimony of growers, have brought out the fact that rice growing in running water suffers little from weevil attacks. In these cases, however, no considerable area has yet been seen in which the water flowed with any perceptible current. To maintain a distinct moving flood over a large field would require an immense supply of water. The instances that have been observed were confined to spots or small plats covered by the inflow of water from a canal or ditch. In spreading onto a field from an inlet the current soon loses force and any low temperature. Where a cool flow of water is pumped from a well directly onto a field the low temperature seems to exert a controlling factor against infestation. But these cases are rare, because the rice demands warm temperatures for vigorous growth, and the sun heat greatly restricts the cool area.

EFFECTS OF DEEP AND SHALLOW FLOODING AND STAGNATION.

Deep water and stagnant water greatly favor development of weevils. As already pointed out, rice in spots or areas of deep flooding is most severely attacked. Severity of attacks is especially

marked in shallow water almost as much as in deep water when either becomes stagnant. In a field that had received only a scant supply of water, which in fact merely filled the low places although keeping all of the ground soaked, very few larvæ could be found. Most of these larvæ occurred on roots of weak plants in the pools, while the best growth stood out of water and was scarcely attacked at all. Soaking instead of flooding appeared to result very beneficially, not only controlling infestation but inducing prime growth of plants at least past the stage of stooling when the coarse leaves offer little attraction to the weevils.

EFFECTS OF EARLY, DELAYED, AND LATE FLOODING.

Rice in different fields that were first flooded at various times covering a seasonal range of dates in accordance with the planting and sprouting has in due course been found subjected to the same degree of infestation. No advantage can be gained against the weevil by choosing any particular time for flooding that will still be suitable for the needs of the plants. An attempt to delay full flooding by a gradual soaking of fields in order that the plants might attain a strong growth and be able to withstand or escape attacks after deep water was applied met with interference from heavy rainfalls which flooded the fields, and the owner then saved the water. The probable effectiveness of soaking is indicated by the case of accidental shortage of water, as mentioned in the preceding subject.

EFFECTS OF ALTERNATE FLOODING AND DRYING.

At Crowley, La., on June 28, inspection was made of a field of rice that had been allowed to dry out from stoppage of water supply on two occasions, one lasting six days and the other four days. The occurrence of larvæ was limited principally to the most heavily flooded parts, and the roots of the plants were not badly injured. The comparative scarcity of the larvæ throughout the field was attributed to the effects of the two intervals of drying, and the rice escaped much danger from attacks.

At Almyra, Ark., on August 1, other observations were made on a field where scarcity of water had caused alternate periods of drying. Water had been supplied but little more than half of the time since first flooding, though the ground had been generally kept damp with the addition of rainfall. No larvæ were found on the roots of this rice, and only a few weevils occurred on weak plants near the edges of the field. The plants exhibited a high, vigorous, and fairly healthy growth, the lack of enough water having evidently resulted in a yellow tinge of the leaves, which, however, promised to be

speedily overcome owing to flooding rains. The crop eventually produced an excellent yield.

USE OF FERTILIZERS AND APPLICATION OF LIME.

In an experiment to determine whether the use of fertilizers and application of lime would serve as a check on weevil infestation, plats for growing rice were prepared at Crowley, La., as shown by the accompanying diagram, which also gives the results of examinations on July 8. The whole field was flooded equally to an average depth of 6 inches. The arrangement and treatment of the plats and status of infestation are outlined as follows:

| | Unlimed. | Unlimed. | Limed, 2,000 pounds per acre. |
|---|-------------------------|----------|-------------------------------------|
| Checks..... | 5 larvæ per 25 stalks. | 1 larva. | 11 larvæ. |
| Acid phosphate, 400 pounds, 16 per cent, per acre..... | 7 larvæ per 25 stalks. | 6 larvæ. | 6 larvæ. |
| Acid phosphate as above plus muriate of potash, 50 pounds per acre..... | 14 larvæ per 25 stalks. | 9 larvæ. | 7 larvæ. |

Total proportionate number of larvæ:

For the check plat..... 17, or $22\frac{2}{3}$ per cent infestation.

For the phosphate plat..... 19, or $25\frac{1}{3}$ per cent infestation.

For the phosphate and potash plat.... 30, or 40 per cent infestation.

Calculating another way from the foregoing outline, the limed areas were found to have 24 larvæ compared with 16 larvæ in the unlimed areas of the same plat, while in the opposite plat 26 larvæ were taken on the roots of the same number of stalks.

No advantage in reducing or retarding infestation appeared to be shown through the application of fertilizers or lime to the soil, but rather the contrary effects are indicated, as the strip with double fertilization contained the most larvæ. Since the plant growth had responded in proportion to the degree of fertilization, the stimulated plants exhibited no signs of injury resulting in yellow appearance of leaves except in the limed areas, which as a whole included the poorest growth on account of the severer pruning of the small root systems.

Further observations made at Midland, La., have led to the conclusion that fertilization does not prevent nor even hinder the propagation of larvæ, but the extra nourishment may assist the plants to overcome attacks.

USE OF TRAP LIGHTS FOR ADULTS.

The appearance of adults at artificial lights at night has suggested the plan of placing lights in the fields and trapping the weevils which may be attracted. Great numbers of the weevils seek the electric lights of stores in the towns throughout regions where the insects abound. Ordinary lights in dwellings are sometimes frequented. At Crowley, La., more than a hundred weevils have been collected within a few minutes on a single store window. They appear most numerous on warm dark nights, but, like many other insects, they do not fly to lights in any considerable number when the moon shines. Neither does the time of their flight seem to last long, for as soon as darkness has settled, most of them come in a rush, and only occasionally do stragglers show themselves later in the night. Their seasonal appearance begins from the 1st to the middle of April, and about the middle of August they become very scarce.

Tests of the efficiency of light as a practical means of attraction were conducted at Crowley. A portable acetylene outfit was used to furnish light, being operated near rice fields 1 mile from town. Some of the best results were as follows, the weevils being taken on a cloth screen that was provided for the purpose of inducing them to alight:

On the night of May 26, 1910, Mr. Van Dine started the light at 8 o'clock and captured over 40 weevils in the first 15 minutes. Later the breeze increased and only strong flying insects came to the light.

Starting the light at 8 o'clock on July 19, after a day of heavy rains, Mr. Hood collected 24 weevils in 45 minutes. But on the night of July 29, which was clear and warm with slight south breeze, he placed the light in the middle of a rice field and caught 125 weevils between 8 and 9 o'clock.

SUGGESTIONS FOR PROTECTIVE TREATMENT.

POISONING ADULTS.

When the weevils gather in particular portions of a rice field, as they often do along deeply flooded edges, dead furrows, and in spots, opportunities seem to be presented whereby the application of a food poison could be made effective. As the weevils indulge in rather extensive feeding compared with their size, the poisoning of the plants would be apt to cause the death of great numbers of the adults that might feed upon the poisoned leaves. The application of the poison should be made upon the first appearance of the insects before they have had much chance to oviposit. The poison must be selected with reference to its safety on the plants, and if in the form of a powder, it could be easily distributed by means of a dust gun, from

which it might be spread for some distance by wind. Probably the only danger would be to live stock having access to the water the drinking of which would be a remote possibility.

CULTURAL MANAGEMENT.

Clean cultural management in dealing with the weevil as with other crop pests is advisable. By restricting the growth of the various grasses and other plants, particularly the objectionable red variety of rice, which grow along and within canals, ditches, and water holes, much advantage could be derived toward the suppression of the breeding of the weevils on the uncultivated host plants. Drainage of bayous, sinks, and water holes would doubtless be of great benefit for the control of the weevil alone.

Leveling of the surface of fields that are to be planted in rice and plowing in such a manner as to avoid dead furrows as much as possible would obviate many of the depressions which on being deeply flooded conduce to a high infestation of the plants in such places.

Finally, a thorough preparation of the soil before planting is to be recommended, in order that grass and weeds may be eradicated without the necessity of deep flooding for the purpose of drowning them. This will permit very shallow flooding with periods of draining or mere soaking of fields for the control of infestation and the betterment of the crops.

SUMMARY.

The rice water-weevil causes more damage to rice crops in the Southern States than any other insect affecting rice plants. When it is in the larval stage it commits severe injuries to rice plants by destroying the roots. Some harm is done by the adults in feeding on the leaves.

The insect chooses food plants that grow in wet places and it breeds only where it finds water. Eggs are evidently laid on roots in water or mud, under which conditions the larvæ hatch, feed, grow, and transform into pupæ, and finally the adults mature and emerge.

Two generations may possibly be produced in a season, but one generation seems to be the rule. Adults pass the winter in hibernation, appearing in spring and invading the rice fields.

The most practical means of controlling the weevil consists in the practice of draining and allowing infested rice fields to dry sufficiently at the proper time or before the attacks of larvæ have greatly weakened the plants. Alternate flooding and drying, if carried out properly, will accomplish the same results. Very shallow flooding or soaking of fields restrains infestation. Fertilization assists the plants to overcome injury.

Considerable numbers of weevils can be captured at lights and destroyed, and the possibility of poisoning them in fields needs to be put to the test. Cultural management should be directed with the view of enforcing every advantage against the weevil that will be consistent with the welfare of the crop.

Approved:

JAMES WILSON,

Secretary of Agriculture,

WASHINGTON, D. C., *April 12, 1912.*

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