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Rice-Field Insects

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INTRODUCTION

Insect enemies of the rice crop differ somewhat from those of other field crops and the methods for controlling them are different, because the rice fields are kept flooded with water during most of the growing period. Insect damage to growing rice is caused mainly by four species. These are the rice stinkbug, two species of lepidopterous stalk borers, and the sugarcane beetle. Other insects mentioned in this circular, however, are capable of causing severe injury to growing rice when conditions become favorable for their multiplication. The important insects attacking rice in the field are described in the following pages and methods for their control are given.

[1] Acknowledgment is made to Jenkin W. Jones, C. E. Chambliss, and J. Mitchell Jenkins of the Bureau of Plant Industry, United States Department of Agriculture, and to C. T. Dowell of the Louisiana Agricultural Experiment Station for cooperation in the work at Crowley.

THE RICE STINKBUG

Practically all rice fields in Louisiana, Texas, and Arkansas suffer losses yearly from the attack of the rice stinkbug (*Solubea pugnax* (F.)) (fig. 1). The stinkbug is also present in all the rice-growing States east of the Mississippi River, but it has not been found in California rice fields.

Description

The rice stinkbug is a straw-colored, shield-shaped bug. When disturbed the adult insect gives off a very strong, disagreeable odor, from which the name of this and other related species is derived. The rice stinkbug may be distinguished from its near relatives by its elongated shape and its sharp shoulder spines, which project forward. The adult is from three-eighths to one-half of an inch long and is slightly less than half as broad. The insect takes its food by means of a long beak, which, when not in use, is folded lengthwise beneath the body.

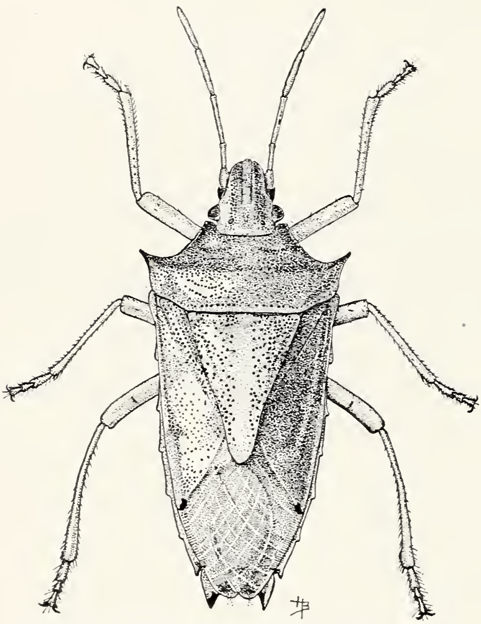

Figure 1.—The rice stinkbug: Adult, × 5.

The eggs (fig. 2, *A*), shaped like short cylinders, are deposited principally on the upper surface of the leaves of rice or grass, although they are sometimes found on the under side of the leaves, on the stems, and on the heads of the plants. On blades of grass or rice they are arranged in 2 rows, the eggs of 1 row alternating in position with those of the other. The number of eggs in a single cluster ranges from 10 to 47. They are light green when laid, but later become darker and develop a reddish tinge before hatching. The average diameter of the egg is 0.63 millimeter.

The freshly hatched nymphs, or young (fig. 2, *B*), are active. They are more nearly round than elongate and average about 1½ millimeters in length by 1 millimeter wide. The head, thorax, legs, and antennae, or feelers, are black; the abdomen is red, marked with two elongate black spots running crosswise. The color of these markings fades into a light tan during the successive molts of the young bug until the last nymphal stage (fig. 2, *C*) when the color of the nymph more nearly resembles that of the adult.

Life History and Habits

This species passes the winter as a mature bug in heavy, reedy grass, near the surface of the ground, where it is protected not only by the grass itself but by accumulations of fuzz from the grass, of dust, and of other refuse. As many as 7 overwintering bugs have been found in a single clump of bullgrass, or Vasey grass (*Paspalum urvillei* Steud.). The bugs emerge from winter quarters late in April or early in May, according to weather conditions, and begin feeding

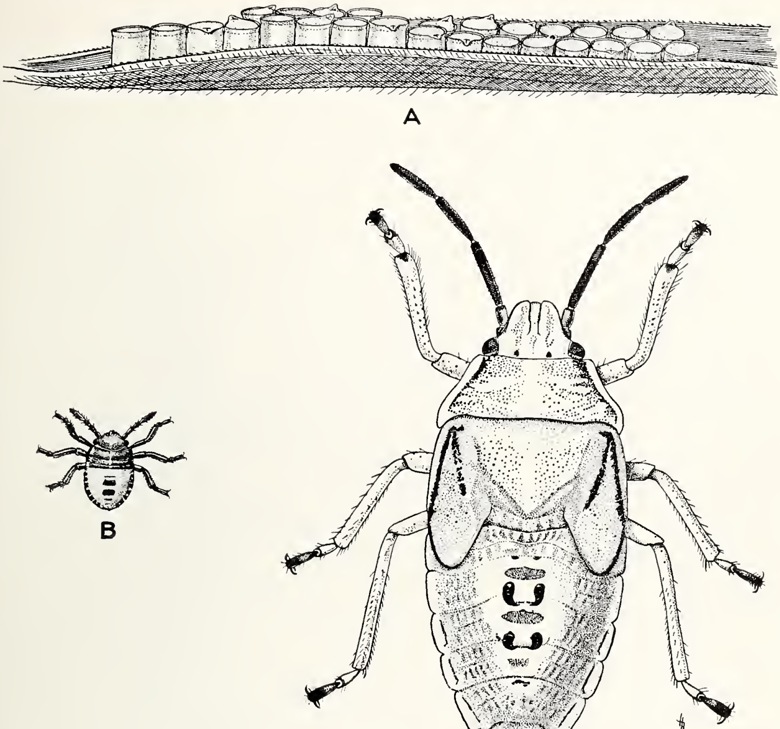

Figure 2.—The rice stinkbug: *A*, Eggs; *B*, first nymphal stage; *C*, fifth (and last) nymphal stage. All × 8.

on a large variety of grasses, preferably those that are producing seed at the time. They begin breeding on the grass, and 2 or 3 generations are produced there. Then, when the rice begins to head, large numbers of adults forsake the grass and attack the rice by extracting the juice from the developing kernels. Some of the bugs continue to feed on grass throughout the season. There may be as many as 4 or 5 generations annually on grass and 2 or 3 on rice. An individual female was observed to lay as many as 150 eggs during life, and another female deposited 138 eggs during a 10-day period. The length of the egg stage ranges from 3 days in hot weather to

11 days in the cool weather of spring. Usually the eggs hatch at the end of 4 or 5 days.

The newly hatched bugs remain together near the eggshells during their first period of growth. Directly after their first molt, however, which usually occurs 2 days after their hatching, each young bug seeks a separate feeding place, generally on the rice panicle, where it begins to suck the juices from the developing kernels. The bugs move from place to place on the plant, growing and changing in shape and coloration and resembling more and more the adult bugs. The nymphs molt five times in from 15 to 28 days and then become adults. The total time elapsing between the egg and the adult stages ranges from 18 to 32 days, or even longer in the cool weather of spring.

About 4 days after reaching the adult stage the females begin to oviposit. Although early observations had indicated that in hot, sunny weather the adults seek the shade on the under side of leaves and in other convenient places during the day, emerging at night to feed, more recent investigations, in the form of surveys with an insect net, showed that the bugs fed in equal numbers at all times of the day from 8 a. m. to 5:30 p. m. The bugs are not often found in grass during hot, sunny weather, for, when the heat becomes oppressive, they seek the cool shade near the surface of the ground.

In summer the length of adult life ranges from a few to as many as 47 days. The adult rice stinkbug is not a very strong flier. It flies only short distances when disturbed, and in the rice field is seldom found in numbers far from the levees or field borders.

Host Plants

Stinkbugs have been observed feeding on the following grasses, which grow in and around rice fields: *Echinochloa crusgalli* (L.) Beauv., *E. colonum* (L.) Link, *Digitaria sanguinalis* (L.) Scop., *Panicum dichotomiflorum* Michx., *Paspalum urvillei* (bullgrass or Vasey grass), and *Phalaris minor* Retz. Of these grasses, the common bullgrass (*Paspalum urvillei*) is by far the favorite wild host. This grass begins to send up culms early in the spring and to form mature panicles by May 1. The same rootstock continues to send up new culms on which panicles are formed until late in the fall, and thus this grass supplies the stinkbugs with suitable food for a period of at least 5 months.

Nature of Injury

The rice stinkbugs, both nymphs and adults, feed on rice kernels in the milk and dough stages. The bugs insert their long, slender, strong beaks through the hull and suck the inner part of the kernel. When the grain is in the milk stage the entire contents are often sucked out, leaving an empty seed coat. When only a portion of the grain's contents are imbibed, the grains suffering such injury are known to the rice trade as "pecky rice." Spots varying in shape and size, and in color from a light yellow with a sort of bleached appearance to black, appear on the kernels after stinkbugs have made punctures. The most common shape is a circular spot about 2 millimeters in diameter, but spots may range from the size of a pin point to one which entirely covers and discolors the kernel. Observations in cooperation with rice pathologists have indicated that similar discoloration is sometimes caused by fungi and that the size of the spot may be affected by certain fungi entering the bug-damaged kernel, thus causing further discoloration. In addition to losses described, stinkbug-injured kernels are more often broken during the milling process than unaffected kernels.

LOSSES FROM PECKY RICE

The extent of losses from pecky rice has been calculated from figures obtained from 1930 to 1937, inclusive, by the Federal-State grading offices [2] in Louisiana, Texas, and Arkansas and the American Rice Growers Association in Texas. In the system of grading rice adopted by the Bureau of Agricultural Economics of the United States Department of Agriculture, one of the items considered is the percentage of damaged kernels. Practically 99 percent of all damaged kernals are pecky. Price deductions for pecky rice are made as the grade decreases with the increase in amount of injury. The amount of this deduction varies with the variety of rice. In calculating the following losses due to pecky rice, deductions for the Blue Rose variety are used since most of the rice grown in Louisiana, Texas, and Arkansas is of this variety. During the year 1934, when disposal of the crop was controlled by the Agricultural Adjustment Administration of the United States Department of Agriculture, all rice was sold under these grades, and the losses for that year are the actual figures. Since that time the same grading system has been more or less followed.

In calculating losses, rice with more than 2 and up to 4 percent pecky was placed in grade 2 with a deduction of 9.45 cents per barrel of rough rice (162 pounds) from the price for grade 1. Rice having more than 4 and up to 7 percent pecky is placed in grade 3, more than 7 and up to 10 percent in grade 4, more than 10 and up to 15 percent in grade 5, and over 15 percent pecky in sample grade.

Loss due to pecky rice in the season of 1930 is shown in table 1.

TABLE 1.—*Loss due to pecky rice in Louisiana, Texas, and Arkansas in 1930, based on a production of 10,285,555 barrels* [1]

Grade No.	Proportion of the crop		Loss due to pecky rice	
			Per barrel	Total
	Percent	*Barrels*	*Dollars*	*Dollars*
1	53.2	5,471,915		
2	35.5	3,651,372	0.0945	345,055
3	9.0	925,700	.2205	204,117
4	1.7	174,854	.3465	60,587
5	.3	30,857	.5355	16,524
Sample	.3	30,857	.7560	23,328
Total	100.0	10,285,555		649,611

[1] 1 barrel=3.6 bushels.

[2] The authors are indebted to W. D. Smith, at that time supervisor in charge of Federal Rice Supervision and Federal-State Inspection Service, Bureau of Agricultural Economics, United States Department of Agriculture, and to Mr. John Coffey, of the American Rice Growers Association, for their cooperation in making their records available for the compilation of these data.

Pecky rice losses so calculated for the years 1930–37 were as follows:

Year:	*Loss*
1930	$649,611
1931	352,191
1932	493,177
1933	644,974
1934	203,774
1935	365,064
1936	629,346
1937	450,625
Total	3,788,762
Average	473,595

In addition to pecky rice, there is a loss due to empty seed coats or what might be termed sterility. The kernels listed as sterile are those that failed to produce a millable kernel. Some of these were not actually sterile, because there was evidence of fertilization, but bugs had sucked out the juices during the early milk stage of development so only a seed coat and no sound or partially sound kernel developed.

In addition to the injury previously discussed, there is a possibility that the stinkbugs are vectors of various rice diseases.

Natural Control

Many stinkbugs have been found dead in their winter quarters, and judging from the small number that survive the cold of winter, this mortality must be considered one of the greatest factors in keeping the insects under control. And similarly, in periods of unusually hot weather numbers of bugs in the nymphal stage have been found dead in places where they were exposed to the sun.

The Fish and Wildlife Service of the United States Department of the Interior has records of eight birds known to feed on the stinkbug. Of these the red-winged blackbird (*Agelaius phoeniceus littoralis*) seems to be the most effective. An undetermined species of black spider has been observed catching the adult bugs on grass plants, but because of its relative scarcity and the fact that it has not been observed in the rice fields it cannot be considered of much benefit. Under laboratory conditions stinkbugs in the third instar have been observed sucking the eggs of their own species, but it is doubtful that this occurs in the field.

The eggs of the stinkbug are destroyed by two species of wasplike parasites, *Ooencyrtus anasae* (Ashm.) and *Telenomus podisi* Ashm. Late in summer a large percentage of the eggs are parasitized by these minute insects. In September 1925 no stinkbug eggs were found in Louisiana that were not parasitized. These parasites are an important factor in reducing the number of bugs in the last, or fall, generation.

Artificial Control

The stinkbug hibernates as an adult in heavy grasses, mainly *Andropogon* spp. and *Paspalum* spp. Burning or plowing under such heavy grasses in the fall or winter must destroy the hibernating adults, but no data are available on the benefit obtained in the next crop from this control measure. Agronomists who have been consulted concerning this practice do not consider it objectionable from an agronomic standpoint. Where the stubble fields are grazed by cattle it would be preferable to wait until late in the winter to burn them.

THE STALK BORERS

Two species of borers feed within the rice stalk. These are the sugarcane borer (*Diatraea saccharalis* (F.)), a major pest of sugarcane and corn in Louisiana, eastern Texas, and Florida, and the rice stalk borer (*Chilo plejadellus* Zincken). Neither of them has been found in Arkansas or California, and only the rice stalk borer occurs in rice in Georgia.

The damage caused by these borers is greater than would be suspected from casual observation, although only a small number of rice stalks are killed outright by them. The injury usually causes the panicles of the infested stalks to turn white, and from the percentage of these conspicuous white heads the injury by the borers is generally estimated. Upon examination, however, as many as 32 percent of the stubs in large fields of rice have been found infested with borers, and it is estimated that a loss of more than 200 pounds of rice per acre has resulted from injury by them. During the growing season the rice stalk is greatly weakened by the tunneling of the borers, and heavy loss from lodging results, especially in windy weather. In late-sown rice many of the young plants are cut so severely just above the water line by the feeding of the numerous little borers that the top of the plant often breaks off. The sapping of the vitality of the plants reduces the yield of the attacked stalks, even of those that mature. The damage from borers is usually heavier in the large-stemmed than in the small-stemmed varieties. In areas where both species attack rice the sugarcane borer is by far the more numerous.

Description

These two species of borers resemble one another in all stages of their life history. They pass through four stages in their life cycle—the egg; the larva, or borer; the pupa; and the adult, or moth.

The sugarcane borer moth (fig. 3) is of a straw color, with the forewings showing darker markings. The forewings of the rice stalk borer moth (fig. 4) are lighter in color, having a golden tinge, and are marked with a sprinkling of minute black dots. The hind wings are white. The size of the moth in either species varies with the amount of food taken by the larva, but averages an inch or slightly more from tip to tip of the spread wings.

The eggs of both species are oval and are flattened on the leaf, where they are deposited in clusters with the individual eggs overlapping so that they form a pattern similar to that of scales on a fish. They are creamy white when laid but develop more of a yellowish color as the incubation period advances. They are laid in groups of from 2 to 100 or more, although the number of eggs usually found in a single cluster is less than 50. It is almost impossible to

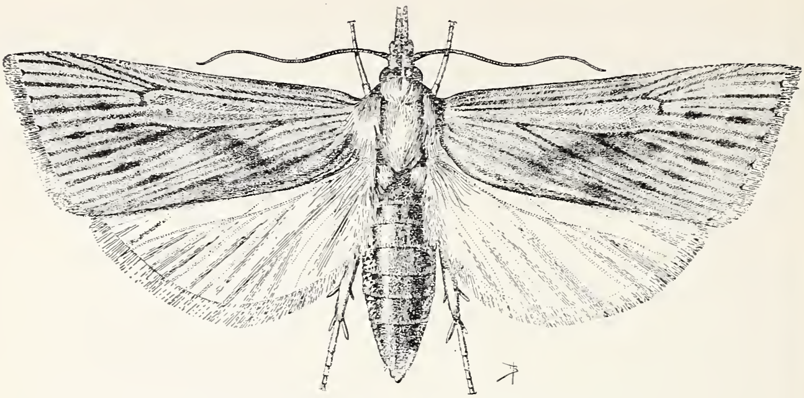

FIGURE 3.—The sugarcane borer; adult female, × 3.

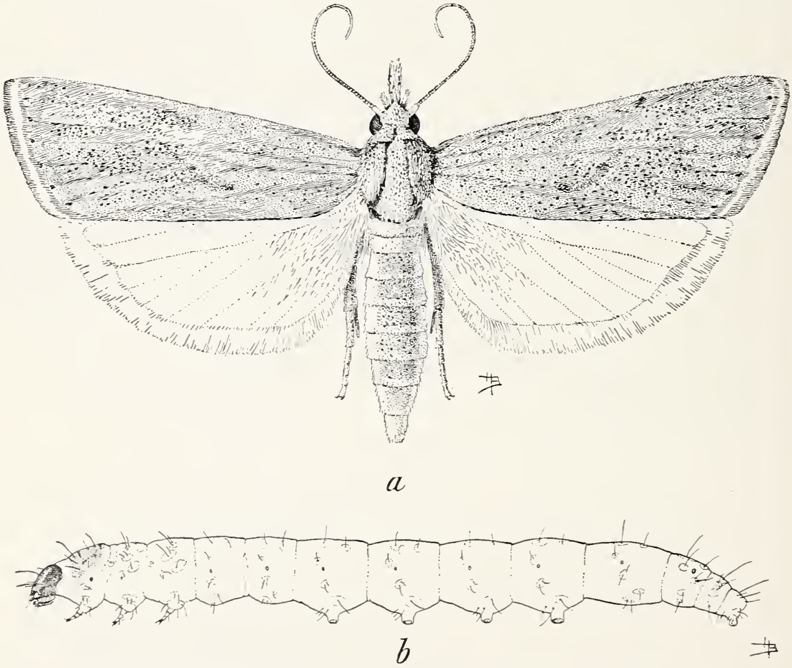

FIGURE 4.—The rice stalk borer; *a*, Adult; *b*, larva. About × 4.

FIGURE 5.—Larva of the sugarcane borer; dorsal view, × 4.

distinguish the eggs of one species of borer from those of the other, but it appears that those of the rice stalk borer are more nearly white when freshly deposited.

The larva of the sugarcane borer (fig. 5) is yellowish white with brown spots. In the winter these spots are absent and the color becomes more deeply yellow. The larva of the rice stalk borer (fig. 6, *A*) is yellowish white, and is marked on each side with a brown stripe running the entire length of its body and a fainter brown stripe below it. These stripes, which are noticeable in both winter and summer, serve to distinguish this larva from that of the sugarcane borer, which has no stripes. The larva of each of these borers is about 1 inch long when full-grown.

The pupae range in color from light to dark brown. The pupa of the rice stalk borer (fig. 6, *B*) is smoother and tapers more evenly to a point at the rear than does that of the sugarcane borer. The pupa of the rice stalk borer is nearly always found enclosed in a heavy web, whereas the pupa of the sugarcane borer (fig. 7) is not so enclosed. The pupae average about two-thirds of an inch in length by one-sixth inch in width.

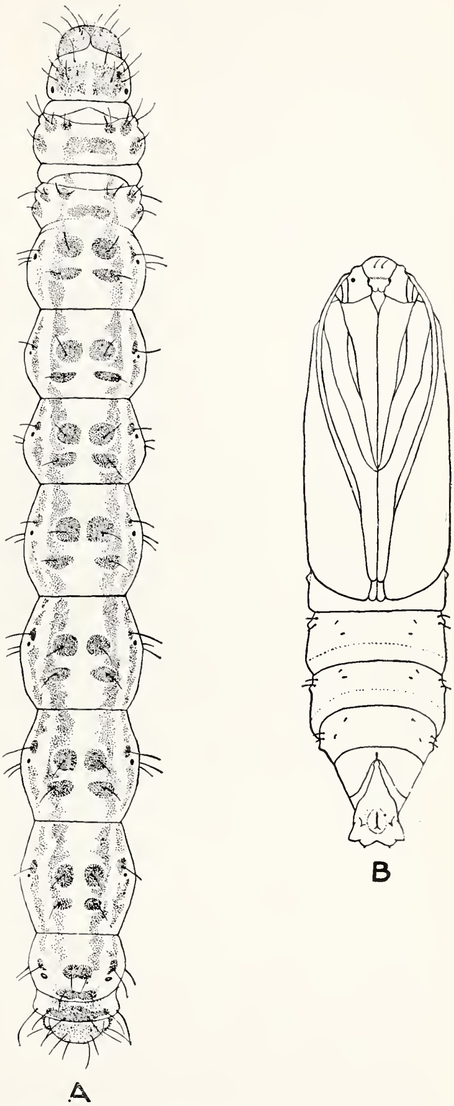

FIGURE 6.—The rice stalk borer: *A*, Larva; *B*, pupa. × 5.

Life History and Habits

Both species of borers spend the winter in the larval stage in rice stalks and stubble. The sugarcane borer hibernates also in grass, corn (to a slight extent), sugarcane, and other plants of the grass family. The rice stalk borer has been found overwintering in three uncultivated grasses. Most of the overwintering larvae of the sugarcane borer in rice are found in the crown of the plant where moisture is available. In most cases where a larva is found above the crown it is surrounded by wet, sawdustlike refuse from the borer. The overwintering larvae of the rice stalk borer are usually found in the joints of the rice stalks, about three joints above the crown, where the plant is dry. They appear to be unable to survive the winter in wet quarters. These larvae also have been found spending the winter in rice straw in the stack. It is believed that sugarcane borers do likewise.

The larvae transform to pupae in the spring. The moths of the sugarcane borer begin to emerge in May. This species breeds on grasses, corn, and sugarcane until the rice plants reach sufficient size to be bored. The moths of the rice stalk borer do not emerge until a later date. Soon after the rice plant has begun to joint, the moths of both species begin to lay eggs on both the upper and lower surfaces of the rice leaves. The egg-laying period of a moth lasts from 1 to 6 days. The number of eggs laid ranges from a few to several hundred, averaging about 200. One female sugarcane borer moth is known to have deposited 203 eggs in a single night. The moths remain concealed during the day, but fly at night, and hence are seldom observed in the field.

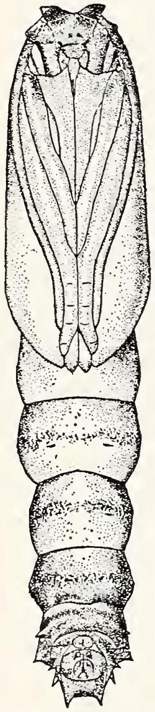

FIGURE 7.—Pupa of the sugarcane borer, × 6.

The eggs hatch in from 4 to 9 days. They may hatch when immersed in water as well as when dry, although when submerged the incubation lasts about 2 days longer. Borers hatched under water crawl up the leaf and out of the water. Borers newly hatched on a leaf above water feed there for a short time, then crawl down and bore into the rice stalk. The larvae, or caterpillars, tunnel up or down the stalk, shedding their skins at intervals and growing until they attain full size. Usually from 24 to 30 days are spent in the caterpillar stage. On reaching maturity they transform inside the stalk to pupae, from which the adult moths emerge in 6 or 7 days. Both species have two or three generations a year in rice fields.

Nature of Injury

After the larvae have entered the stalks they are fairly safe from their natural enemies, as well as from any artificial control that man may apply. No dust or spray can reach them.

The larvae eat the inner part of the stalks and continue to enlarge and lengthen their tunnels until only a thin wall is left around them. The attacked stalk usually remains green prior to heading, but when the panicle emerges from the boot of a seriously injured stalk the glumes, or hulls, turn white immediately. This condition is commonly called "whitehead." Such panicles produce no grain and are therefore a total loss. Sometimes the plant is far enough advanced to have the panicle completely exserted from the sheath when the feeding larvae cut off the flow of plant food. When injury occurs at this stage, the panicle partly matures, but this condition prevents a uniform development of seed. The resulting light, immature grains do not mill well, and their capacity for germination is greatly reduced.

Another type of injury occurs which is far less noticeable but of much economic importance. When the panicles are practically mature, a percentage of them are lost because the larvae have girdled the uppermost node, leaving the upper part of the stem with little support. The stem is easily broken off at the injured node by the wind or harvesting machinery, resulting in a loss of the panicles. The actual loss from borer damage is rather hard to estimate because of this and other types of injury not so readily apparent.

Host Plants

Holloway, Haley, Loftin, and Heinrich [3] record the following food plants of the sugarcane borer: Sugarcane, corn, broomcorn, kafir, Johnson grass (*Sorghum halepense* (L.) Pers.), milo maize, sorghum, Egyptian wheat, Sudan grass (*Andropogon sorghum* var. *sudanense* (Piper) Hitchc.), Para grass (*Panicum purpurascens* Raddi), vetiver (*Vetiveria zizanioides* (L.) Nash), red sprangletop (*Leptochloa filiformis* (Lam.) Beauv.), giant broomsedge, and rice. Jones and Bradley [4] also record *Panicum purpurascens*, Vasey grass (*Paspalum urvillei* Steud.), *Panicum gymnocarpon* Ell., *P. dichotomiflorum* Michx., *Sorghum halepense* (L.) Pers., and *Andropogon glomeratus* (Walt.) B. S. P. as food plants. In addition to these the writers have found this borer in pearl or cattail millet, and Shallu. *Chilo plejadellus* has been found attacking rice, *Zizania aquatica* L., *Zizaniopsis milacea* (Michx.) Doell and Aschers., and *Spartina cynosuroides* (L.) Roth.

Extent of Injury

In surveys for whiteheads caused by borers in 1929, 0.83 percent of the early rice and 1.63 percent of the late rice stalks exhibited this type of injury. In 1930 whiteheads made up 0.43 percent of the early rice and 1.17 percent of the late rice.

From 1927 to 1933 stubble of early and late rice in southern Louisiana was examined for borer injury shortly after the crop was harvested. Two hundred stubs were examined in each field sampled and samples were taken at representative locations throughout the rice-growing area. In making the collection of stubble, care was taken to get a few stubs from all parts of each field. The stubs were examined by splitting each one from the crown to the top with a sharp knife. The position, size, and species of the larvae found were noted, as well as the number of larvae per stalk. The results of these examinations are given in table 2.

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[3] Holloway, T. E., Haley, W. E., Loftin, U. C., and Heinrich, Carl. The sugarcane moth borer in the United States. U. S. Dept. Agr. Tech. Bul. 41, 77 pp., illus. 1928.

[4] Jones, Thos. H., and Bradley, W. G. Certain wild grasses in relation to injury to corn by the "borer" (Diatraea saccharalis Fab.) in Louisiana. Jour. Econ. Ent. 17: 393–395. 1924.

TABLE 2.—*Number of rice stubs injured by borers in representative fields in southern Louisiana*

Year	Stubs examined	Stalks injured	Year	Stubs examined	Stalks injured
	Number	*Percent*		*Number*	*Percent*
1927	7,400	16.45	1932	15,400	2.90
1928	6,000	2.52	1933	3,400	6.20
1929	5,400	5.62			
1930	4,800	2.25			
1931	4,200	12.21	Average infestation for 7-year period		6.88

The average number of stalks per acre is about 1,633,500. Based on this figure and the average percentage of infested plants, an average of 112,384 plants per acre are injured by the larvae of the stalk borers. Since the majority of these injured stalks fail to produce any grain and since borer injury, especially of the node-injury type, is not always apparent in stubble examinations, the percentage loss is probably as great as the percentage of injured stalks. This would give a reduction in yield of approximately 124 pounds per acre on the basis of 1,800 pounds, which is the average acre yield in Louisiana.

Varietal Preference

Observations indicated that there might be a difference in varietal susceptibility to borer injury. Examinations to determine differences in varietal infestations were made in variety experiment plots at the Rice Experiment Station at Crowley, La. The results are given in table 3.

TABLE 3.—*Susceptibility of varieties of rice to borer infestation at the Rice Experiment Station, Crowley, La.*

Variety	Stalks bored [1]		1933		Average
	1928	1930	Stalks examined	Stalks bored	
	Percent	*Percent*	*Number*	*Percent*	*Percent*
Blue Rose	16.5	8.0	800	6.5	10.3
Fortuna	9.5	12.5	1,500	.7	7.6
Rexoro	7.0	10.0	800	3.0	6.7
Acadia	13.0	2.5	700	1.3	5.6
Delitus	10.0	1.0	1,100	.4	3.8
Honduras		5.5	600	1.0	3.2
Wataribune		4.0	500	.7	2.3

[1] 200 stalks of each variety examined.

Beginning in 1931 a study was made of the commercial varieties of rice to determine the plant characters associated with the various degrees of varietal susceptibility to borer injury. Each variety was sown in a one-tenth-acre plot, the plots being situated side by side, on as nearly uniform land as could be obtained at the Crowley Rice Experiment Station. These plots were separated by a space wide enough to permit separate harvesting. Observations were begun at the time of seeding and continued until the rice was harvested, after which stubble examinations were made. Each year from 1931 to 1933, inclusive, data were obtained in these plots on the variety, date of seeding, shade of green in the stalks, date of maturity, size of stalks, yield per acre, and average borer infestation of stalks.

The effect of size of stalks on borer infestation is shown graphically in figure 8 and the effect of date of maturity in figure 9. Figure 10 shows the effect of shade of green in the stalks on the percentage of stalks bored. These data, based on the examination of 19,200 stalks, indicate that the size of stalks is more closely correlated with the degree of borer infestation than is the shade of green.

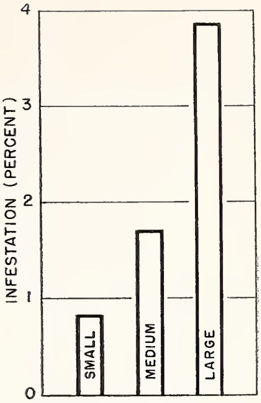

FIGURE 8.—Relationship of size of rice stalks (small, medium, and large) to degree of borer infestation.

The most comparable figures are for the 20 varieties having medium dark-green, small stalks with the 19 varieties having medium dark-green, large stalks. In figuring the average infestation for the 3-year period it was found that the former varieties had an average infestation of 0.77 percent, while the latter had an average of 5.40 percent. This seems to be rather conclusive evidence that varietal susceptibility to borer injury varies more with size of stalk than with depth of coloration.

FIGURE 9.—Relationship of date of maturity of rice to degree of borer infestation.

Natural Enemies

The eggs of both species of borers are parasitized by the minute wasp *Trichogramma minutum* Riley. Efforts have been made to increase the effectiveness of this parasite on the sugarcane borer by mass liberations of the wasp early in the season in sugarcane fields, but these releases have been of no value in Louisiana. Another wasp-like parasite, an undescribed species of *Microbracon*, has been found to destroy the larvae of both species, but it appears to be present in numbers too small to be of much value.

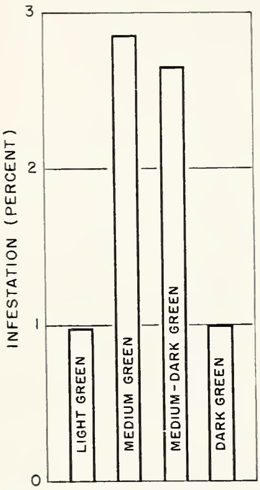

Figure 10.—Relationship of shade of green in the stalks of rice to degree of borer infestation.

In an effort to control the sugarcane borer attacking sugarcane, 13 species of parasites have been introduced and released in sugarcane fields in the continental United States. Four of these appear to have possibilities of value in controlling this borer, namely, the flies *Lixophaga diatraeae* (Towns.), *Theresia claripalpis* (V. d. W.), and *Metagonistylum minense* (Towns.), and the wasp *Bassus stigmaterus* (Cress.). In August 1936, 35 mated females and 5 males of *L. diatraeae* were released in corn adjoining rice fields at Crowley. In July 1939, 74 Amazon flies (*M. minense*) of the Sao Paulo strain were released in corn adjoining rice fields near Crowley. No recoveries have been made of either of these species in the rice-growing area. *T. claripalpis* was reared on larvae of the rice stalk borer in the laboratory, but attempts to rear *M. minense* on larvae of this species were unsuccessful.

Climatic Control

Owing to the small amount of protection from cold afforded larvae by rice stalks there is a heavy mortality when low temperatures occur. Rice stubs were examined each year for 5 years to get data on the mortality of the stalk borers due to low temperatures. The percentage of mortality for each year was as follows:

Winter of—	*Mortality (Percent)*
1931–32	14.8
1932–33	61.9
1933–34	14.3
1934–35	52.2
1935–36	67.3

Data obtained over a period of years indicate that there is a marked relationship between winter weather and the amount of borer infestation in the following rice crop. The infestation almost invariably runs higher following mild winters. Table 4 gives the number of freezes, lowest temperatures, and rainfall for the winters preceding each crop and the borer infestation following, from 1926–27 through 1932–33.

Table 4.—*Effect of winter-weather conditions on the borer infestation in the crop following, Crowley, La.*

Year	Days of freezing temperatures	Minimum temperature	Rainfall	Infestation
	Number	*°F.*	*Inches*	*Percent*
1926–27	8	25	22.79	16.45
1927–28	16	19	21.27	2.52
1928–29	22	24	23.66	5.62
1929–30	21	19	37.75	2.25
1930–31	9	30	22.85	12.21
1931–32	5	27	31.57	2.90
1932–33	16	25	25.93	6.20

The two lowest infestations on record are 2.52 and 2.25 percent and both followed a minimum temperature of 19° F. during the preceding winter. It may also be noted that a low infestation occurred in 1932 following a minimum temperature of 27°, but this temperature was recorded on March 10 after the larvae had become active and pupation had already begun as a result of a mild February and early part of March. This condition apparently resulted in a heavy larval mortality and a greatly reduced borer infestation.

Control Methods

PASTURING OR BURNING STUBBLE

Data obtained indicate that fairly heavy pasturing of stubble fields reduces the number of overwintering larvae by approximately 75 percent. Burning of stubble also decreases the number of overwintering borers to some extent, but this practice is, of course, undesirable if cattle are to be pastured in the field.

FALL PLOWING OF STUBBLE

Many stubs have been examined from fields that were plowed during the fall, and the data show that less than 1 percent of the hibernating larvae lived through the winter in stubble fields that were properly plowed in the fall.

WINTER FLOODING OF STUBBLE

Experiments conducted in 1928 indicated that a rather high mortality of overwintering borers was obtained by closing rice field levees and allowing the winter rains to submerge the stubble of the previous rice crop. In 1929 a carefully controlled experiment was begun to determine whether submerging would give effective control of larvae hibernating in rice stubs. This experiment was conducted over a period of 4 years, using water at depths of 5 inches, 3 inches, and barely covering the surface of the soil. Each treatment and an untreated check were replicated three times. Although a fairly high percentage of the overwintering borers were killed, the mortality was not high enough to make this method practical. The highest average mortality (40.16 percent) resulted in the plots covered with 5 inches of water.

An experiment was conducted each year for a period of 4 years in which an ordinary flat drag was run over the stubs in order to mash them to the ground and kill the borers hibernating in them. This method killed considerable numbers of borers.

Since each of these methods appeared to be of some value in decreasing the number of overwintering borers, it was decided to combine them. Accordingly, an experiment was conducted over a 3-year period in which a $\frac{1}{10}$-acre plot of stubble was divided into two plots the first year and into four the following 2 years. An ordinary flat row drag was run over half of the plots to mash the stubble to the ground, and the levees were closed to hold the precipitation. Untreated check plots were also included in the experiment. Table 5 gives the data obtained at each examination for the 3 years during which this experiment was conducted.

TABLE 5.—*Effect of dragging and submerging rice stubble on mortality of overwintering borers*[1]

Treatment given	Period of submergence after levees were closed	Borers, dead		Borers, alive		Mortality
		In crown	Above crown	In crown	Above crown	
	Days	*Number*	*Number*	*Number*	*Number*	*Percent*
1933 (1 PLOT OF EACH TREATMENT)						
Dragged and submerged	21	0	3		3	50
	35	0	2	0	1	67
	76	0	3	0	0	100
	81	0	2	0	0	100
Submerged only	21	1	0	0	2	33
	35	0	3	0	0	100
	76	0	2	0	1	67
	81	0	3	0	1	75
Check, no treatment	21	0	1	1	1	33
	35	0	2	0	0	100
	76	0	3	0	1	75
	81	0	1	0	1	50
1934 (2 PLOTS OF EACH TREATMENT)						
Dragged and submerged	30	1	1	0	1	67
	48	2	3	0	0	100
	54	1	4	0	0	100
Submerged only	30	2	1	2	4	33
	48	1	2	1	0	75
	54	1	0	0	4	20
Check, no treatment	30	0	0	1	1	0
	48	0	1	1	3	20
	54	0	1	2	2	20
1935 (2 PLOTS OF EACH TREATMENT)						
Dragged and submerged	22	1	2	6	0	33
	29	0	1	2	2	20
	36	0	6	2	0	75
	43	1	6	0	1	88
	50	0	4	0	0	100
	57	0	4	0	0	100
Submerged only	22	0	2	5	1	25
	29	0	2	7	2	18
	36	0	4	2	3	44
	43	0	2	3	2	29
	50	0	0	0	2	0
	57	0	5	0	4	56
Check, no treatment	22	0	10	7	0	59
	29	0	1	6	1	13
	36	0	5	2	1	63
	43	0	1	1	0	50
	50	0	1	2	0	33
	57	0	3	5	0	38

[1] 100 stubs were examined in each plot.

It may be noted from table 5 that a final borer mortality of 100 percent was obtained each year by dragging and submerging.

According to Chambliss and Jenkins,[5] the average rainfall for a period of 14 years for December was 6.60 inches and for January 5.16 inches. The average evaporation for the same period was 2.226 inches for December and 1.8 inches for January. This indicates that with closed levees there should be no necessity of pumping water on the fields. It was never necessary to pump water on the land in the experiments reported on. Farmers in southwestern Louisiana have also closed rice fields levees for various reasons and have been successful in holding water on the stubble fields without the expense of pumping during the winter months. The cost of closing levees and dragging stubble at this time of year is very low, as this operation comes at a time of the year when farmers are not busy with other farm operations. Many farmers claim that keeping the land submerged during the winter increases the yield per acre. The Rice Experiment Station has, however, conducted a series of tests to determine the effect of winter submergence on yield. Through the courtesy of the Bureau of Plant Industry of the United States Department of Agriculture and of the Louisiana Agricultural Experiment Station the results of these experiments are given in table 6. These results show that there was no significant increase or decrease in yield due to winter submergence.

TABLE 6.—*Annual and 4-year average acre yields of Fortuna rice grown in triplicate plots to determine the effect of holding water on rice lands in alternate years when not seeded to rice, Rice Experiment Station, Crowley, La.*

Treatment in previous winter	1936	1937	1938	1939	Average
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Water held on rice stubble	22.5	23.0	25.1	27.8	24.6
Water held on plowed land	25.6	28.9	23.1	27.4	26.3
Check, not submerged	18.7	28.9	25.9	26.8	25.1

KEEPING CORN AND SUGARCANE FROM VICINITY OF RICE FIELDS

When rice and corn or rice and sugarcane are grown in the same vicinity, the borer infestation is usually heavier in both crops than where one is grown in the absence of the other. This increased infestation results from moths flying from rice stubs and thus supplying a heavy spring infestation to the corn or cane. These two crops then serve as a breeding place in the spring for borers which later attack rice when it has reached a sufficient size to support borers. It is estimated from actual field counts, made during March and April for each of 5 years, that an average of 42,471 borers successfully overwinter in each acre of rice stubble in Louisiana.

THE SUGARCANE BEETLE

The sugarcane beetle (*Euetheola rugiceps* (Lec.)) has been found to injure rice in all the southern rice-producing States. It has not

[5] CHAMBLISS, CHARLES E., and JENKINS, J. MITCHELL. EXPERIMENTS IN RICE PRODUCTION IN SOUTHWESTERN LOUISIANA. U. S. Dept. Agr. Bul. 1356, 32 pp., illus. 1925.

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been found in California. The most severe injury observed by the authors was in southwestern Louisiana, especially in the northern portion of the rice area, where fields are scattered among large areas of heavily pastured sod land that afford food for the larvae. Occasional severe infestations also occur at points in the rice section where there are apparently no very favorable breeding grounds. Heavy infestations usually can be accounted for by the presence of nearby breeding grounds, but these sporadic infestations in fields that are surrounded by rice fields or other cultivated crops indicate that adults may fly for considerable distances.

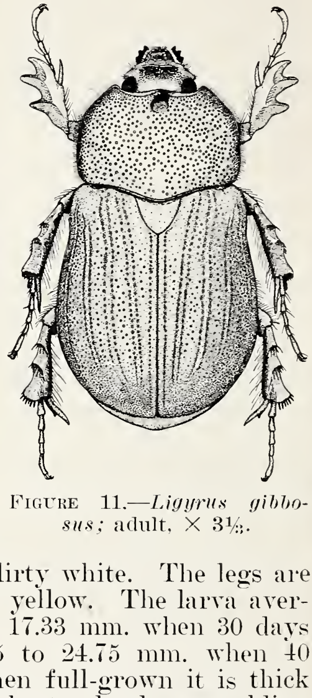


FIGURE 11.—*Ligyrus gibbosus*; adult, × 3⅓.

Description of Stages

The egg, which is deposited in the soil, is somewhat oblong when first laid and is pure white. It increases in size and becomes more globular with age. Eggs at full size average about 1½ mm. in diameter. They are deposited singly, and each egg is enclosed in a ball of compacted soil ranging from one-fourth to one-half inch in diameter.

The larva varies from pure white to a dirty white. The legs are yellowish, and the head shield is a reddish yellow. The larva averages 4.5 mm. in length when 21 days old, 17.33 mm. when 30 days old, and 21.25 to 24.75 mm. when 40 days old. When full-grown it is thick bodied and robust, closely resembling a white grub. It may be distinguished from these grubs, as well as from the larva of *Dyscinetus trachypygus* (Burm.) and other similar larvae found in rice areas, by the irregular, double row of modified bristles which appear on the last ventral segment. For these distinguishing characters see plate 1.

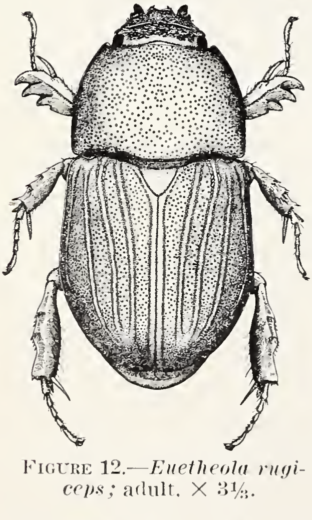
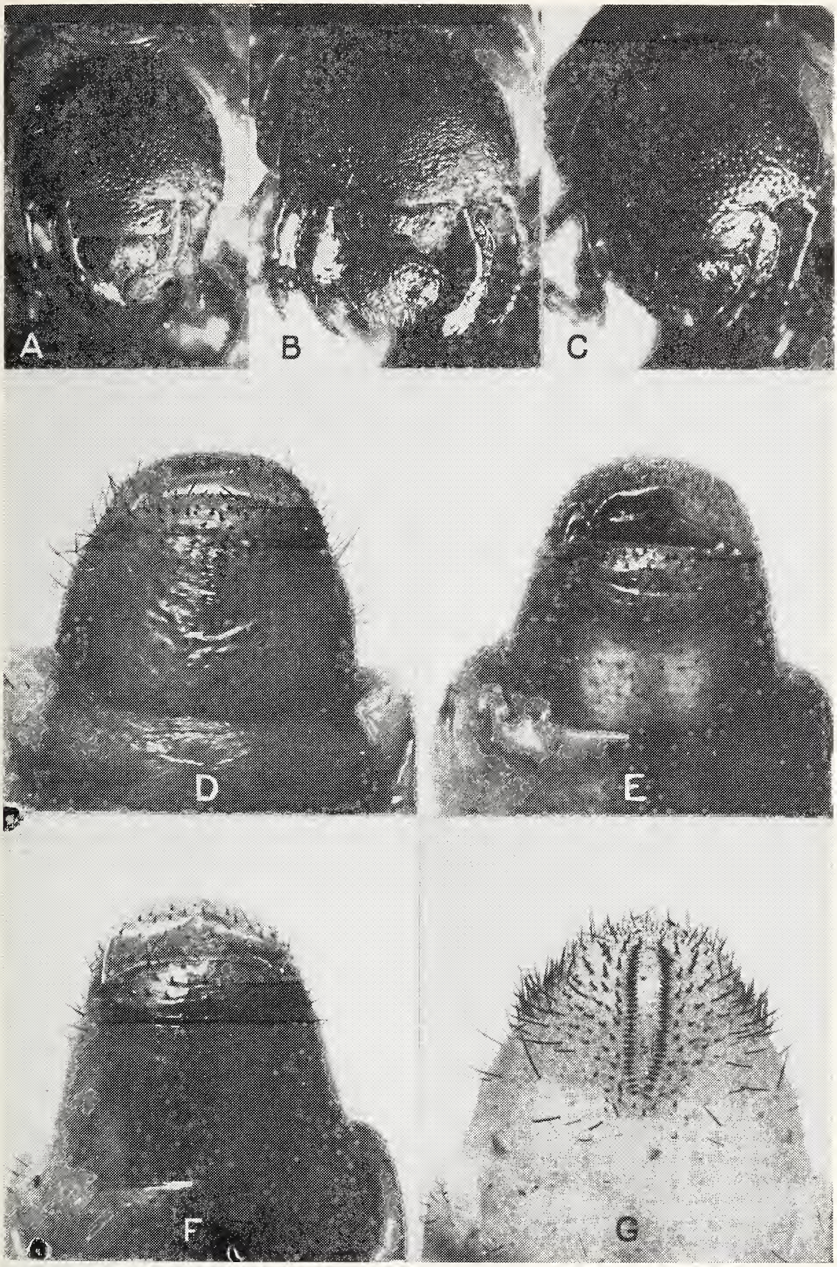


FIGURE 12.—*Euetheola rugiceps*; adult, × 3⅓.

The adult is a rather robust beetle and averages about 15 mm. in length. When first transformed it is a shiny jet black but this becomes dull with age. Overwintering beetles can be readily distinguished from newly emerged ones by this difference in luster. The adult may be distinguished from adults of *Phyllophaga*, or May beetles, by its black color, smaller size, and somewhat depressed form. The adults of *D. trachypygus* and of the carrot beetle (*Ligyrus gibbosus* (Deg.)) are the ones most likely to be confused with those of the sugarcane beetle. The adult of *Dyscinetus* is



THE SUGARCANE BEETLE AND SPECIES LIKELY TO BE MISTAKEN FOR IT

A, Frontal view of head of larva of *Euetheola rugiceps*, showing the strongly punctate surface; *B*, frontal view of head of larva of *Ligyrus gibbosus*, showing its relatively smooth surface; *C*, frontal view of head of larva of *Dyscinetus trachypygus*, showing its strongly punctate surface; *D*, ventral view of anal region of larva of *E. rugiceps*, showing median double row of modified bristles on last segment; *E*, ventral view of anal region of larva of *L. gibbosus* (note absence of any trace of a median double row of modified bristles on last segment); *F*, ventral view of anal region of larva of *D. trachypygus* (note entire absence of a median double row of modified bristles and relative coarseness of bristles); *G*, ventral view of anal region of larva of *Phyllophaga* sp., showing sharply differentiated median double row of modified bristles on last ventral segment. (Photographs by J. H. Paine.)

somewhat larger and the sides of its abdomen are more rounded. The adult of the carrot beetle is approximately the same size as that of the sugarcane beetle, but may be distinguished by its reddish-brown cast and hairy ventral surface. Another distinguishing character is the gibbous pit or depression on the middle front of the thorax of the carrot beetle, which is absent in the sugarcane beetle. For differences in adults see figures 11 and 12.

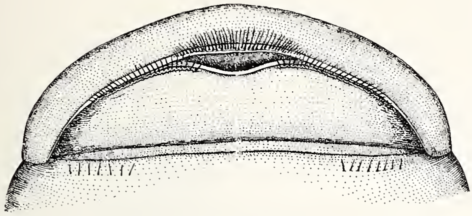


Figure 13.—Ventral view of tip of abdomen of adult male of *Euetheola rugiceps*, showing structural characters.

The sexes of the sugarcane beetle may be distinguished by the presence on the male of a fringe of short, stiff hairs on the tip of the abdomen, which is broadly interrupted in the middle by a hairless interval behind which there is a short postanal fringe. In the female this fringe of hairs is continuous without a median break (figs. 13 and 14).

Life History and Habits

Adult sugarcane beetles overwinter in the soil. Well-drained sod land is the most suitable hibernating place. The adults begin emerging in March and continue their spring activities through May and a part of June. They attack various cultivated crops at this time. The crops that suffer most injury in Louisiana, Texas, and Arkansas are rice, sugarcane, and corn. The beetles gnaw the plants just below the surface of the soil and often kill or so stunt them that they never make a normal growth. After feeding, the adults deposit eggs, preferably in sod land near cultivated fields. Eggs and larvae were found, however, in cultivated row crops and in unsubmerged knolls and levees in rice fields. Larvae have been found in sod land near rice fields to the number of 10,700 per acre.

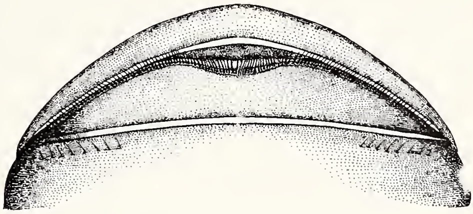


Figure 14.—Ventral view of tip of abdomen of adult female of *Euetheola rugiceps*, showing structural characters.

The earliest date on which eggs were observed is April 23. The average incubation period for eggs under laboratory conditions was 14 days, the average larval period was 85 days, and the average pupal period 9 days. One female was estimated to have deposited about 35 eggs. Beetles of the new generation emerge in August and September. They feed for a period before going into winter quarters. No eggs are deposited until the following spring.

Nature of Injury

In the spring the adults fly by night into rice fields that have not been submerged and gnaw the young plants just below the surface of the soil. The plants are chewed into threads at the point of attack and in most cases die immediately. An adult often starts in a drill row and gnaws a number of consecutive plants. One female has been known to gnaw more than 100 plants. When rice fields are submerged the beetles leave them and go into sod land or attack other crops. At flooding time many of the beetles in the fields drift to levees and attack the rice growing on the unsubmerged part of the levee. In some areas, where there is usually a heavy beetle infestation, a very poor stand of rice remains on the levees after the beetles have fed there. Adults of the new generation go into rice fields in the fall as soon as the fields are drained to allow the land to dry for harvesting operations. At this time the adults gnaw the mature stalks at or just below the surface of the soil and cause the stalks to fall over out of reach of the harvesting machinery. Fields have been observed that were injured to such an extent that the rice had the appearance of having been blown flat by a severe windstorm.

Amount of Injury

The amount of injury varies considerably from year to year and in different localities of the rice belt. Table 7 gives the average damage to unsubmerged young rice in representative fields from 1929 to 1935 and the average amount of injury to mature plants after the fields had been drained preparatory to harvesting for 1931 to 1933.

Table 7.—*Sugarcane beetle injury to unsubmerged rice in the spring and to rice drained for harvesting, southern Louisiana, 1929–35*

Year	Fields examined	Stalks examined	Stalks gnawed by beetles	
	Number	*Number*	*Number*	*Percent*
UNSUBMERGED YOUNG RICE				
1929	8	1,600	91	5.69
1930	5	1,000	189	18.90
1931				
1932	14	1,900	429	22.58
1933	9	4,500	289	6.42
1934	6	3,000	377	12.57
1935	12	6,000	192	3.20
MATURE PLANTS IN FIELDS DRAINED PREPARATORY TO HARVESTING				
1931	21	4,200	202	4.81
1932	6	1,200	119	9.92
1933	5	1,000	56	5.60

Natural Enemies

There are many natural enemies of this beetle, and the manner in which rice fields are handled aids these enemies greatly in reducing the number of adults, especially in the spring. When fields of young rice are flooded the adults crawl out of the ground and float and swim until they are picked up by birds, until they reach the levee, or until they become exhausted and drown. Birds are numerous in rice fields when the first irrigation water is applied. The following species have been found feeding on the adult beetles: Gulf Coast red-winged blackbird (*Agelaius phoeniceus littoralis*), killdeer (*Oxyechus v. vociferus*), fish crow (*Corvus ossifragus*), red-winged blackbird (*Agelaius phoeniceus*), meadowlark (*Sturnella magna*), boat-tailed grackle (*Cassidix mexicanus major*), English sparrow (*Passer domesticus*), bluebird (*Sialia sialis*), and black-bellied plover (*Squatarola squatarola*).

Skunks eat quantities of these beetles, and the armadillo is an important natural enemy in eastern Texas, where this animal is found in great numbers. The skunks capture the adults or larvae by digging neat little holes with their front feet. The armadillo prefers the adults and captures them by rooting up the soil with its nose in the same manner as does a hog.

The common toad (*Bufo lentiginosus*) and the bullfrog (*Rana catesbiana*) eat the adults.

The adult beetle is parasitized by the larva of a fly, *Sarcophaga rapax* Walk. The beetle larvae are also parasitized by another dipteron, *Microphthalma disjuncta* (Wied.). As many as one-third of the larvae have been parasitized by the latter species, but generally neither species appears to be of much importance in beetle control.

During the summer of 1934, 530 females and 9 males of the scoliid wasp *Campsomeris dorsata* (F.) were introduced from Puerto Rico and released in beetle-infested areas in southern Louisiana. Although this species attacks larvae of a related beetle in Puerto Rico, it apparently failed to survive in Louisiana. In the laboratory the species was bred through to the cocoon stage on *Euetheola rugiceps*, but no adults were obtained.

A shipment of 200 specimens of the giant toad (*Bufo marinus* L.) was received from Puerto Rico in May 1936. One-half of these were released in a heavily infested area near Franklin, La. The others were placed in breeding pens or released near Angola, La. No recovery of this toad has been reported.

Control Methods

A number of repellent or insecticidal chemicals have been applied to infested sugarcane rows under conditions approximating those of unsubmerged rice. None of these proved of economic value in beetle control. Sodium arsenite used in baits killed beetles when the bait was fed upon, but no bait has been devised that was attractive to the beetle.

The treatment of rice seed with kerosene or commercial coal tar was found effective under controlled conditions. These odorous materials actively give off fumes during the period of 15 days that is allowed the rice for the dry growth period prior to submerging. In these trials they did not injure germination or growth of the rice in any way.

Seed rice was treated with kerosene at the rate of one-half gallon per bushel and allowed to remain in a container over night. No difficulty was experienced in using a regular drill for seeding rice so treated.

The method of treatment with commercial coal tar was to pour a small stream of coal tar steadily into the container of seed and stir the seed until it became covered with the material. If the seed is treated with tar, it is necessary to add road dust, flour, or some other well-pulverized material to overcome the stickiness of the tar. About 1 quart of commercial coal tar will treat a bushel of seed.

The kerosene or coal tar seed treatment might be used to advantage under certain conditions. However, the fields should be watched closely for wilting plants and irrigation water applied as soon as injured plants appear.

No treatment has been found that is effective in repelling the beetles in the fall after the fields are drained. In sections where beetle injury is common, draining should be delayed as long as possible, as the beetles will not attack rice so long as the surface of the soil is covered with water.

Since sod land is preferred by the beetle for breeding, elimination of sod land is advantageous when it fits in with the farming system.

THE RICE WATER WEEVIL

In practically all rice fields in the South the roots of the rice plant are to some extent attacked by the so-called "root maggot," which is the young, or grub, of a grayish-brown weevil called the rice water weevil (*Lissorhoptrus simplex* (Say)). The results of the feeding of the "root maggot" are most noticeable near the base of the plant, where many of the roots are pruned off (fig. 15). The adult insect, which is a snout beetle, or weevil, feeds on the leaves, and slitlike feeding scars remain as evidence of its work. In some fields of late rice the weevils have been so numerous and their feeding so heavy that some plants were killed as a result of the shredding of the leaves.

Description

In its life history the rice water weevil undergoes four distinct stages—the egg; the larva, or grub; the pupa, or resting stage; and the adult. The adult (fig. 16) is normally grayish brown, a darker shade marking the center of its back. When moist, however, the weevil assumes a greenish tinge. A newly transformed adult ranges from very light gray to dark gray, or from purplish and bluish black to solid black. Sometimes the color is a very light gray, mottled with black. The head, thorax, and wing covers of these newly emerged weevils have a glossier, brighter finish than have those of the old weevils. The adult water weevil is about one-eighth of an inch long and about half as broad as long.

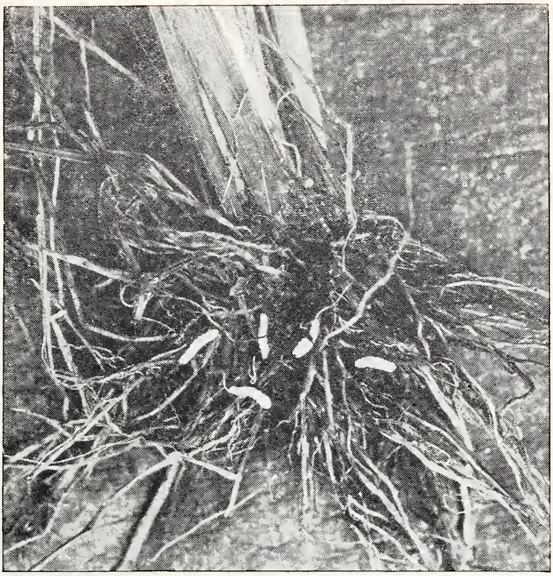


FIGURE 15.—Rice "root maggots" among the roots of a rice plant.

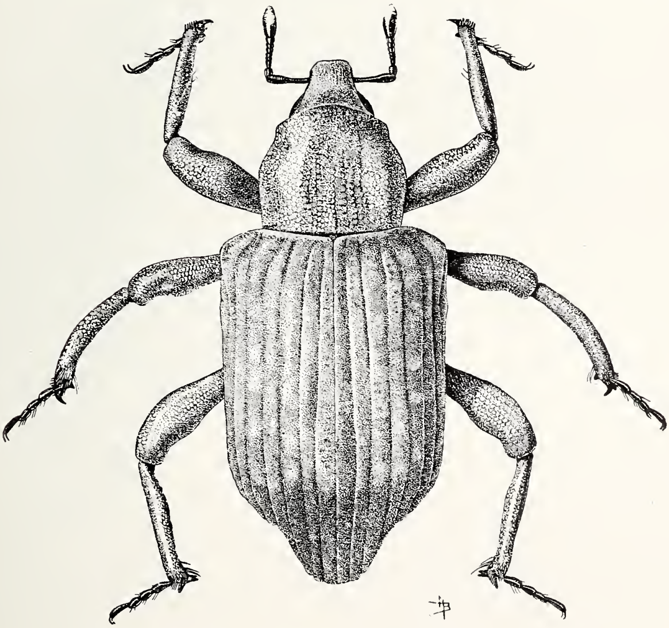


FIGURE 16.—The adult rice water weevil, × 23.

The egg, which is laid in the roots of the rice plant, is pure white, cylindrical, and about four times as long as broad. It can barely be seen with the naked eye.

The body of the larva, or grub, is legless and milky white. Its head is very small in proportion to the body and is brown. Upon reaching full growth the larva measures from one-fourth to one-half of an inch in length and is very slender. The body is encircled by a number of heavy ridges.

The pupa, or resting stage, is milky white and is invariably enclosed in a cell of mud. This cell is very smooth on the outside and is oval. It is found attached to rice roots (fig. 17).

Life History and Habits

The adult rice water weevil lives throughout the winter, its favorite winter quarters being in fine, matted grass. In spring, as soon

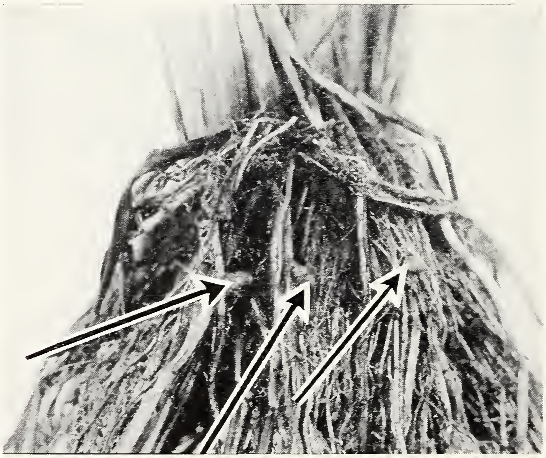


Figure 17.—Pupal cells of the rice water weevil attached to rice roots.

as the rice comes up, the weevils begin to leave their winter shelter and enter the rice fields. They feed at night on the rice leaves, making slitlike longitudinal feeding scars on the upper surface of the leaf, the under side remaining intact. The width of the feeding scar is equal to the width of the mouth parts of the weevil, and its length ranges from a small fraction of an inch to more than 2 inches. When the fields are dry, the weevils hide during the day in the soil at the roots of the rice plants. After the fields are submerged the weevils feed by day as well as by night. When disturbed, they promptly feign death, if they are not in the water. They feed on grass throughout the season, but are most numerous in the spring and the latter part of summer. Weevils have also been found feeding on corn and sugarcane.

When the field is submerged the female weevil begins to lay eggs in the roots of the young rice. She chews a small hole in the root, reverses her body, and by means of a pink-colored, pipe-shaped ovipositor inserts the egg under the outer covering of the root.

The eggs hatch in about 7 days. The young larvae at first feed inside the root, hollowing out the interior, but when they become larger they feed externally on the roots. The length of the larval stage is from 4 to 5 weeks, and possibly longer.

When full grown the larva, or "maggot," forms around itself an oval cell of mud, attached to the roots of the host plant, and it then transforms to the pupa, or resting stage. In from 5 days to 2 weeks an adult weevil emerges. The total length of time elapsing between the egg and adult stages ranges from 35 to 48 days. Two generations of weevils occur annually. Larvae have been observed in rice as late as September 20, and both larvae and pupae occur in fields of headed rice. Before the rice begins to head, most of the adult weevils leave it and seek fields of younger rice or else fly to grass nearby, where they feed on the tender leaves at night and hide during the day. Their feeding on grass diminishes as the season advances. The latest date on which weevils were observed to be feeding on grass was September 16, when the longest feeding slit found measured only one-eighth of an inch in length. In July, August, and September the weevils fly at night in search of places in which to feed or hibernate. They are attracted to lights and have been captured at lights as far as a mile from the nearest rice fields.

Determination of Losses Resulting From Weevil Injury

Draining the submerged fields to control weevils has been the common practice when the rice looked sickly or yellow. The work of draining is troublesome and expensive, however, as it involves the cutting of the levees and their subsequent reclosing, and causes a considerable waste of water in resubmerging. The grower who pumps from his own well is put to extra labor and expense, or the canal company that furnishes water also to other farmers must spend more money for pumping. In dry years in Louisiana, when much of the fresh water is pumped from the streams, salt water may enter from the Gulf, and thus an excessive percentage of salt may be present in the irrigation water and injurious to the rice.

Great trouble and expense would be justified in the control of a serious pest, but as far back as 1922 there was a suspicion in the minds of a few rice growers that the water weevil could not be so classed. After 11 years of observation J. Mitchell Jenkins, Superintendent of the Rice Experiment Station, Crowley, La., concluded that the damage caused by the "root maggot" in Louisiana is very small.

Observations made in 1923 showed that the so-called "root maggot" injury was often caused by soil conditions, deep water, grass, and other factors unfavorable to rice culture.

It was therefore decided that, before further control work on the rice water weevil was done, experiments should be made to determine the amount of injury caused by its feeding. Accordingly in the spring of 1924 a screened cage was constructed, 17 by 39 feet and 6 feet high, above the rice levee. This cage, as well as the later ones, was covered with 18-mesh screen wire which was known to prevent the entrance or escape of water weevils. There was a screen-wire partition in the center, dividing the cage into two equal parts. In the spring of 1926 three additional cages were constructed. These were 18 by 40 feet and 6 feet in height. Except in size, they were exact replicas of the first cage.

The land on which the cages were located was typical rice land. It was prepared and the rice seeded in rows 8 inches apart, as is the most common local field practice. The Fortuna variety of rice was used in 1924 and 1925 and the Blue Rose in the years following. A margin was allowed on all sides of the cages. The area actually planted in each side within the first cage was 16 by 14 feet, or 224 square feet, and within the last 3 cages 18 by 16 feet, or 288 square feet. The irrigation water was run into the cages through pipes having their openings covered with fine screen to prevent the entrance of water weevils. Just before or immediately after the submerging, all weevils that could be found were collected from both sides of the cages. Weevils were then released in one side of each of the cages, while the other side was kept free from them. The side in which weevils were released was alternated each year. The number released annually was 450 in the first cage and 612 in each of the other cages. These numbers were selected as representing the largest number of water weevils found in the rice under actual field conditions.[6] The weevils for the cages were collected from rice fields prior to, or at the time of, submerging the land.

The height of 10 plants growing in each side of each cage was recorded about 3 weeks after the fields were flooded and at intervals thereafter. Throughout the season an attempt was made to approximate as nearly as possible the actual field conditions in the cages. The water in them was drained prior to harvest, and the rice was cut and shocked inside the cages. Later the rice was threshed and the grain and straw produced in each side of each cage were weighed. Results are given in table 8.

TABLE 8.—*Weights of grain and straw produced in cage experiments on water-weevil injury, Crowley, La., 1924 and 1926–29*

Cage No.	1924		1926		1927		1928		1929	
	Infested	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested	Uninfested
WEIGHT OF GRAIN										
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1	10.37	9.62	4.87	3.87						
2			13.50	11.50	10.13	8.75	7.40	7.50	10.50	11.50
3			7.00	8.37	14.25	13.25	5.10	6.20	13.75	11.00
4			6.75	7.75			8.10	7.80	7.00	7.50
WEIGHT OF STRAW										
1	32.00	33.80	[1] 13.60	[1] 13.80						
2					18.20	18.00	13.60	14.80	15.00	15.75
3					31.20	28.20	26.80	27.20	21.50	24.00
4							19.20	17.20	15.00	16.25

[1] Figures obtained in 1925.

[6] In determining the number of weevils to be released, counts were made in flooded rice fields by means of a screen frame 2 by 2 by 2 feet. The frame was set down in a rice field and counts made of the weevils inside. About 10 minutes was taken for each count to allow weevils beneath the water to come to the surface. A count was made in five places in each field and the result of the five counts averaged. The largest number of weevils found in a rice field was 2 per square foot.

The total weight of the grain produced in the infested sides of all cages was 118.72 pounds, while the total weight in the uninfested sides was 114.61 pounds. From these figures it appears that the insect had no appreciable effect on the yield of grain.

The total weight of the straw in the infested side of the cages was 206.1 pounds, while the total weight of that from the uninfested sides was 209 pounds. Thus it is evident that the weevil had little effect on the weight of straw. It might be mentioned here that a heavy yield of straw is not desired by the rice planters.

In 1926 heavy rains followed the threshing, and the straw began to rot before it was dry enough to be weighed; therefore no weights for the straw were obtained. In 1925 rats destroyed a part of the grain in the shock on the uninfested side, consequently when weighed it was several pounds less than in the infested side, and these figures were not placed in the grain-weight tables.

To determine whether lighter grains resulted from the feeding of the "root maggot," 5 lots of 100 grains each from each side of the cages were husked and weighed. The average weight for 100 grains from the infested side was 2.146 grams and that for 100 grains from the uninfested side, 2.150 grams. Two other lots of 500 grains each were weighed and gave for the infested side 10.67 grams and for the uninfested side 10.68 grams. It thus appears that the presence of the water weevil does not cause lighter grains.

It was found that the rice plants in the infested side were generally shorter than in the uninfested side when examined 3 or 4 weeks after the fields were submerged.

During the years while the screen-cage experiment was running, field observations were made to supplement the experimental data. It was found that, as a general rule, all rice takes on a sickly, yellowish color about 3 weeks or a month after it is first flooded. This change in color may be due to holding the water too deep, to a shortage of available nitrogen, to unfavorable conditions for root aeration, to changes in the root system, or to other causes. It is at this time that the rice is said by the planters to be suffering from "root maggot" injury. Sometimes the rice leaves develop a reddish tinge and many die. Fields have been examined in which all but the top leaves were dead. On examination, it was usually found that few rice water weevils were present, while a larger number were present in the roots of healthy plants nearby. Many times this condition was found to be due to the fact that the water was so deep that only the topmost leaves were above the surface. In other cases it was apparent that soil conditions were the cause of the poor appearance of the rice. In some fields grass was so thick that the rice had a stunted, sickly appearance.

The Rice Experiment Station at Crowley conducted experiments during the years 1934–39 to determine the effect of various submergence treatments on yield. Results of the experiments are given in table 9 through the courtesy of the Bureau of Plant Industry of the United States Department of Agriculture and the Louisiana Experiment Station. In three of the treatments the soil was dried out sufficiently to kill "root maggots." As shown in the table, however, all these practices resulted in decreased average yields as compared with that of plots which were continuously submerged. Since continuous submergence gives the best condition for "root maggots," it is evident that injury from "root maggots" is not sufficient to justify drainage.

TABLE 9.—*Average yields per acre for years 1934–39 in manner-of-submergence experiment conducted by the Rice Experiment Station, Crowley, La.*

[Data show that treatments 2, 3, and 4, in which "root maggots" were killed by drying out of land, resulted in decreased yields]

Treatment	Year	Yield per acre for treatment							
		1		2		3		4	
		Lb.	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*	*Bu.*
(1) Submerged 10 days after seedling emergence. Water held continuously	1934	1,886	41.9						
	1935	1,089	24.2						
	1936	1,262	28.0						
	1937	1,638	36.4						
	1938	2,707	60.2						
	1939	1,863	41.4						
(2) Submerged 10 days after seedling emergence. Drained 3 weeks later. Resubmerged after land dried out	1934			2,000	44.4				
	1935			965	21.4				
	1936			1,415	31.4				
	1937			1,249	27.8				
	1938			2,145	47.7				
	1939			1,151	25.6				
(3) Submerged at time of seedling emergence. Water allowed to evaporate until land dried out, then resubmerged	1934					1,414	31.4		
	1935					692	15.4		
	1936					1,285	28.6		
	1937					1,229	27.3		
	1938					2,321	51.6		
	1939					1,727	38.4		
(4) Submerged at time of seedling emergence. Water allowed to evaporate until land dried out, then resubmerged. Four weeks later drained and land allowed to become dry again before being submerged	1934							1,567	34.8
	1935							677	15.0
	1936							1,483	33.0
	1937							1,074	23.9
	1938							1,673	37.2
	1939							1,467	32.6
Total		10,445	232.1	8,925	198.3	8,668	192.7	7,941	176.5
Average		1,741	38.7	1,488	33.1	1,445	32.1	1,324	29.4

From the results of the cage experiments and the manner-of-submergence experiments, and also from extensive observations, it may be stated that in Louisiana the loss to the rice crop from "root maggot" injury is negligible, and that draining undertaken for the purpose of killing the insects is not worth while. Draining may, however, be necessary and worth while in order to correct other unusual ills heretofore said to have been caused by the "root maggot." It may also be possible that the larvae are associated with heavy root rot injury.

MISCELLANEOUS RICE INSECTS

The insect with the greatest possibilities of becoming a more important pest of rice is probably *Paromius longulus* (Dall.). This hemipterous insect may be responsible for a certain amount of pecky rice. The adult is flat, slender, and dull brown. It is common in all rice fields in Louisiana and Texas and is very abundant in some fields. Indications from caged plants infested by *P. longulus* are that these bugs puncture rice kernels and cause circular spots somewhat smaller than those caused by the rice stinkbug. The wild host plants and general habits of *P. longulus* are very similar to those of the stinkbug, and control measures applicable to one would probably be effective against the other.

Sporadic outbreaks of the southern grass worm or fall armyworm (*Laphygma frugiperda* (A. and S.)) (fig. 18) have been recorded at irregular intervals and in widely separated localities. When these worms attack a field of young, unflooded rice they soon devour the leaves and stems. Rice, no matter how young, should be submerged as soon as these larvae are noticed. They will not feed under water and can be controlled effectively and quickly by covering the plants with water. A recurrence of the larvae is not likely in any field that has been submerged.

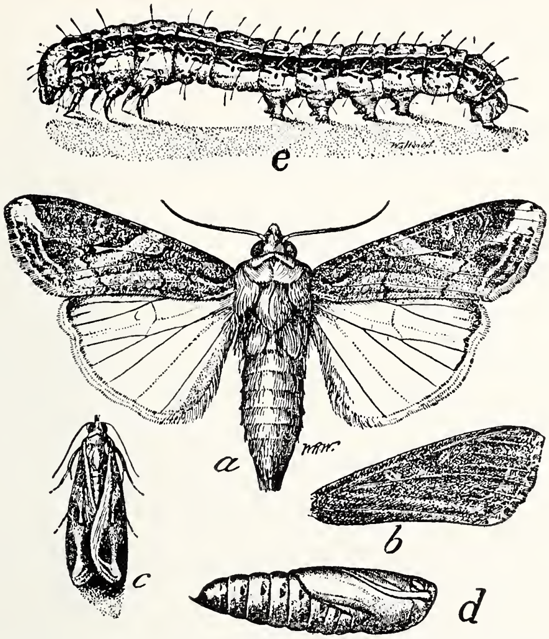


Figure 18.—Southern grass worm or fall armyworm: *a*, Male moth; *b*, right front wing of female moth; *c*, moth in resting position; *d*, pupa; *e*, full-grown larva; *a*, *b*, *d*, *e* about × 2; *c* slightly enlarged.

The larvae of the southern corn rootworm (*Diabrotica duodecimpunctata* (F.)) (fig. 19) attack young rice seedlings and kill every plant that is attacked. These small yellow "worms" bore into the main root or stem and thus prevent the plant from sending up shoots. In certain localities, especially in semireclaimed marshland sections, these larvae may be present in numbers sufficient to cause serious injury to the stand of rice. The adults (fig. 20) inhabit rice fields and feed to some extent on rice pollen. The larvae may be controlled by submergence of young rice. If the rice is not far enough advanced to be submerged for the growing period, the field can be submerged for 3 or 4 days and then drained.

Figure 19.—The southern corn rootworm, × 4½.

The chinch bug (*Blissus leucopterus* (Say)) (fig. 21) is of very minor importance in Louisiana and Texas. It is a small sucking bug, only about one-sixth of an inch long when full-grown. This insect, however, has been responsible for heavy losses to stands of rice in Arkansas. This is due to the migration of chinch bugs from spring oats to young rice before it is large enough to be submerged. Both adults and young bugs, or nymphs, attack rice. They suck the sap from the stems near the ground surface and sometimes beneath the surface of the soil, and when present in large numbers cause the plants to wither and die. They have been known to cause sufficient damage to necessitate reseeding. This insect can be controlled by the application of irrigation water.

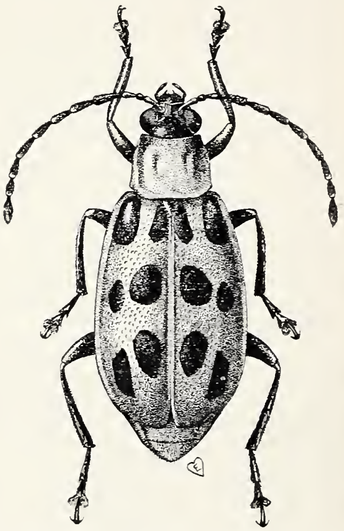


FIGURE 20.—The 12-spotted cucumber beetle, adult of the southern corn rootworm, about × 8.

In addition to this preflooding injury, Isely and Horsfall[7] have observed injury to rice in head late in the summer in Arkansas. In this type of injury the chinch bugs crawled on foot into rice fields in large numbers after the fields had been drained, and attacked the plant stems at the nodes, under the leaf sheaths, and were very noticeable in clusters below the panicles. The rice panicles were blasted as a result of the injury. Although the injury was not extensive, the loss in most cases was nearly total as far as the bugs had migrated. These writers report that the migration of bugs was stopped by the flooding of canals surrounding the fields or by submerging the fields, and that late-season injury can also be decreased by burning over chinch bug-infested grasslands about a week before drainage for harvesting is necessary.

A flea beetle, *Systena frontalis* (F.), has been observed feeding on the leaves of rice, though the injury has been small.

FIGURE 21.—Chinch bugs, × 2.

Among other insects that have been observed attacking rice are a leaf roller, grasshoppers, and a number of sucking insects. The damage caused by them, however, is seldom serious enough to attract much attention.

[7] ISELY, DWIGHT, and HORSFALL, WILLIAM R. THE CHINCH BUG AS A RICE PEST. Kans. Ent. Soc. Jour. 4: 70–73. 1931.

INSECTS IN CALIFORNIA RICE FIELDS

No serious insect injury has been recorded in California rice fields. There have, however, been local instances of injury by grasshoppers, flea beetles, and the larvae of the western spotted cucumber beetle (*Diabrotica soror* Lec.) on young unflooded rice. There seems to be no immediate danger of an outbreak of injurious rice insects in California. There are, however, four species of insects which are of potential importance and should be watched. These are a pentatomid, *Thyanta custator* (F.), the above-mentioned chrysomelid (*Diabrotica soror*), and two species of grasshoppers (*Melanoplus differentialis* (Thos.) and *Conocephalus fasciatus vicinus* Morse). *Thyanta custator* is listed as an insect of possible importance because it very probably feeds on the developing rice kernels and causes pecky rice. This insect, as determined by the senior author in 1939, was not sufficiently numerous to cause enough pecky kernels to affect the grade of the rice. The highest percentage of pecky rice found in commercial rice fields in California was 0.49 percent, whereas a No. 1 rice is allowed up to 2 percent pecky.

A check up on insects of California rice fields in September 1939 did not reveal the presence of any of the rice insects that are important in the rice-growing areas of Louisiana, Texas, and Arkansas. The nearness of the rice-growing area of California to the port of San Francisco, however, exposes it to the introduction of serious rice pests from the Orient. It is highly important that the efforts to prevent the entrance of injurious rice pests from other parts of the United States and from foreign rice-growing countries, which apparently have so far been successful, be continued by both the growers and public agencies in order that the California rice-growing area may continue to be comparatively free of injurious insects.

SUMMARY

There are four major insect enemies of the growing rice crop in the Southern States. These are the rice stinkbug, two stalk borers, and the sugarcane beetle.

The stinkbug sucks the contents from the developing rice grain, causing a total loss of the kernels attacked in the early stages of their development. Later injury results in a spotted or sometimes distorted grain called pecky rice. Annual losses from pecky rice in Louisiana, Texas, and Arkansas are estimated at a half million dollars. Burning or plowing under heavy grasses in which the bugs hibernate decreases the number of overwintering stinkbugs. Winter mortality from cold is one of the greatest factors in keeping down the number of stinkbugs, and parasites are very effective against the fall generation in Louisiana.

Both the sugarcane borer and the rice stalk borer feed within the rice stalk, the former being by far the most numerous. Losses result from the death of the developing rice panicle, a decrease in the growth and development of the affected plants, the breaking off of injured panicles, and the lodging of injured stems. Annual losses in Louisiana are estimated at about 7 percent of the crop. The adult moths deposit eggs on the leaves, and from these the larvae hatch.

The larvae feed for a few days on the leaves and then bore into the rice stalk. Both stalk borers hibernate in rice stubble and in other large grasses. There is a heavy winter mortality due to cold spells, and two native and four imported parasites attack various stages of the borers. Pasturing, plowing, or burning rice stubble fields in winter decreases the number of overwintering borers. The combination of dragging and submerging stubble fields in winter has resulted in a 100 percent mortality of borers.

The adult sugarcane beetle gnaws young rice plants prior to the flooding in the spring, and newly emerged adults attack the nearly mature stalks when the field is drained prior to harvest. In the spring most plants die as a result of the injury. When injured after drainage, the affected plants often fall over and thus are prevented from being picked up by harvesting machinery. Many species of birds, the common toad, the bullfrog, the skunk, and the armadillo feed on the beetles. A predator and a parasite have been introduced for beetle control but apparently have not become established. Seed treatment with kerosene or commercial coal tar has been effective against spring injury under controlled conditions. Application of irrigation water drives the beetles from the field. Prior to harvest, delayed drainage or immediate reflooding after the appearance of beetles is of value in decreasing losses. Elimination of sod land breeding areas is of value.

Larvae of the rice water weevil feed upon the roots of the rice plant, and the adults attack the leaves. Although this insect has previously been considered an important pest of rice, experiments and observations indicate that in Louisiana water weevil injury is negligible, and that draining for the purpose of killing water weevil larvae is not worth while.

Several other species of insects injure rice to only a small extent, or they cause heavy damage only rarely.

No serious insect injury has been observed in California rice fields.

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