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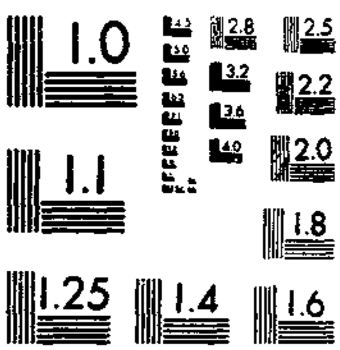

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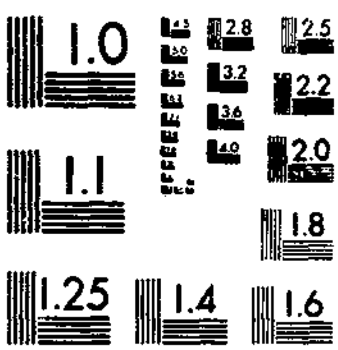

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Insects and Fungi As Causes of Pecky Rice[1]

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INTRODUCTION

Rice kernels bearing spots are known to the trade as pecky rice. These spots are injuries caused by stink bugs or disease organisms. The annual loss from pecky rice in Louisiana, Texas, and Arkansas for the period 1930–38 was about $463,000.[2] An estimate of losses from pecky rice, compiled in 1937, is summarized by Hyslop.[3]

Pecky rice causes considerable loss to both rice growers and rice millers. In milling, the pecky rice breaks more easily than the sound rice, which means that the percentage of head rice is lowered while the percentage of broken rice is increased. The black spots on the milled rice lower the market price of such rice. Because the milling quality of rice containing high percentages of pecky kernels is low and the market value of the milled rice from such lots is also low, the farmer receives less from the miller for rice containing pecky kernels than for rice that is free of this defect.

In addition to pecky rice, the loss due to empty florets, a condition of sterility, is also caused by stink bug injury. This type of loss has been estimated at $3,000,000 per year.

[1] Submitted for publication May 12, 1950.

[2] This figure is based on the rice handled by the grading office of the Federal Rice Supervision and the Federal-State Inspection Service of the Grain Branch, U. S. Production and Marketing Administration, and the available records of rice sales.

[3] Hyslop, J. A. losses occasioned by insects, mites, and ticks in the united states. U. S. Bur. Ent. and Plant Quar. E-444, 57 pp. 1938. [Processed.]

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In 1933 investigations were begun by the Bureau of Entomology and Plant Quarantine, in cooperation with the Bureau of Plant Industry, to determine the relative importance of insects and fungi in the production of pecky rice, and also to devise methods of prevention. These preliminary studies, conducted at Crowley, La., and Beaumont, Tex., indicated that the rice stink bug (*Solubea pugnax* (F.)) and two fungi, *Helminthosporium oryzae* van Breda de Haan and *Curvularia lunata* (Wakker) Boedijn, were largely responsible for the condition. In 1934 the writers started a series of experiments to determine the relative importance of insects and fungi in causing pecky rice. The results of these investigations that have not been published previously [4 5 6] are reported in this bulletin.

DESCRIPTION OF INJURY

Field observations made by Ryker and Douglas [7] showed that the highest percentages of pecky rice occurred in a field that was severely infested with *Helminthosporium* and also had a high stink bug population.

The present writers found that pecky rice falls into three symptom groups. The first type, most commonly spoken of as "pecky," is the insect stigmonose, or so-called O type (fig. 1, *A* and *B*). This is a roughly circular lesion, in some cases shrunken, and with or without discoloration. The second type is characterized by a general brown-to-black, or occasionally yellow or red, discoloration of the whole or part of the kernel. In a few cases, small, black sclerotial bodies may be found under the kernel coat in this type of injury. Such kernels are referred to as discolored, or D type (fig. 1, *D*). The third, or L type is characterized by a linear black discoloration, usually on the base, but it may be on the tip or side of the kernel (fig. 1, *C*). The kernel coat is usually broken. Because the O type has generally been known to growers and rice graders as pecky, that term will be used to designate the stigmonose type of injury in this paper. The other types will be called either the discolored or the L type.

Insect feeding, or extreme damage by fungi, also results in a high percentage of so-called sterility. In this type of injury only the shriveled kernel coat is found inside the glumes, and in the studies reported in the present paper these kernels have been classed as sterile, although actually the condition is the result of extreme damage by one or both of the agencies involved, rather than true sterility. This error in classification was unavoidable because no practicable method was found for separating the actually sterile florets from those severely damaged by insects. The extent of this type of damage can, however, be approximated by a comparison of the number of florets listed as sterile in any given treatment group with the average number in the control lots, which were screened to exclude insects.

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[4] DOUGLAS, W. A. ENTOMOLOGICAL INVESTIGATIONS (RICE FIELD INSECTS). Rice Expt. Sta., Crowley, La., Bien. Rpt. 1933-34: 23. 1934.

[5] ——— STUDIES OF RICE STINKBUG POPULATIONS WITH SPECIAL REFERENCE TO LOCAL MIGRATION. Jour. Econ. Ent. 32 (2): 300-303, illus. 1939.

[6] ——— RICE FIELD INSECTS. Rice Expt. Sta., Crowley, La., Bien. Rpt. 1937-38: 17-19. 1938.

[7] RYKER, T. C., and DOUGLAS, W. A. PECKY RICE INVESTIGATIONS. Rice Expt. Sta., Crowley, La., Bien. Rpt. 1937-38: 19-20. 1938.

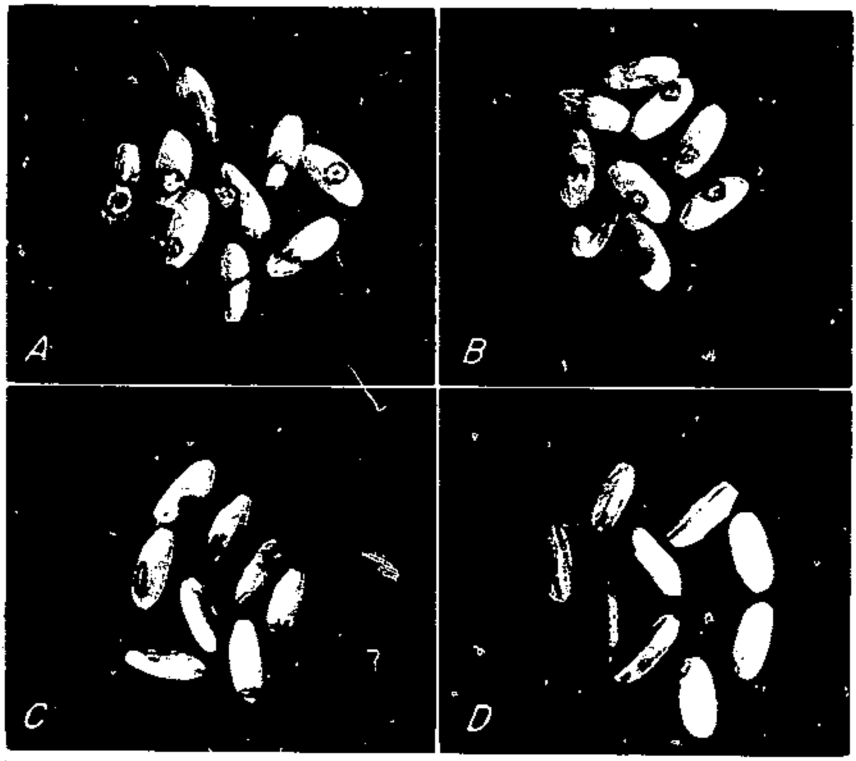

FIGURE 1.—Various types of pecky rice: A, Caused by *Solubea pugnax*; B, caused by *[illegible]*; C, [illegible] type of injury; D, the six grains at the left are damaged by [illegible], the two at the right are normal. [illegible]

METHODS OF STUDY

GROWING EXPERIMENTAL PLANTS

Galvanized sheet iron was made into cans 16 inches square and 16 inches deep with a drain at the bottom edge of each can. These cans were placed in the ground so that their tops were level with the surface of the soil and 4 feet apart to allow an equal amount of sunlight for the plants in each can after a cage was placed thereon. The cans were filled with [illegible] top soil, 1 to [illegible] inches being left at the top for irrigation water, which was applied later. Two rows of Blue Rose rice ([illegible] 4 inches from each side of the can and 8 inches apart) were sown in each can in April. The seed was sown rather thickly and as soon as all the seed had germinated and the plants were high enough to be pulled out without harm, they were thinned to 25 plants per row, or 50 plants per can. The soil in the cans was submerged immediately after the plants were thinned, and the cans containing the plants were then enclosed by wood-framed cages 5 feet tall and built to fit tightly on the cans. The cages were covered with one of three materials: 18-mesh galvanized screen, 32-mesh copper screen, or cellulose-coated screen on one side and domestic sheeting on the other three sides.

The soil in the cans was kept submerged until the rice was practically mature, and then the cans were drained. This treatment gave the caged rice the same growing conditions as rice in commercial fields, except that all but minute insects were excluded or included as desired. After the cages were placed on the cans, 6-inch boards were nailed, box-fashion, around the bottom of each cage, and the space between was filled with soil to prevent insects from crawling up between the frame and the can. Round holes about 8 inches in diameter were cut in the materials used for cage coverings, and cloth sleeves were tied into knots that could be untied when it became necessary to put insects into the cages with the rice or to remove them. By using this method there was very little danger of contamination by insects other than those introduced into the cages. In discussing treatments, notations were made as to the type of material used for cage coverings. Cages used in these experiments are shown in figure 2.

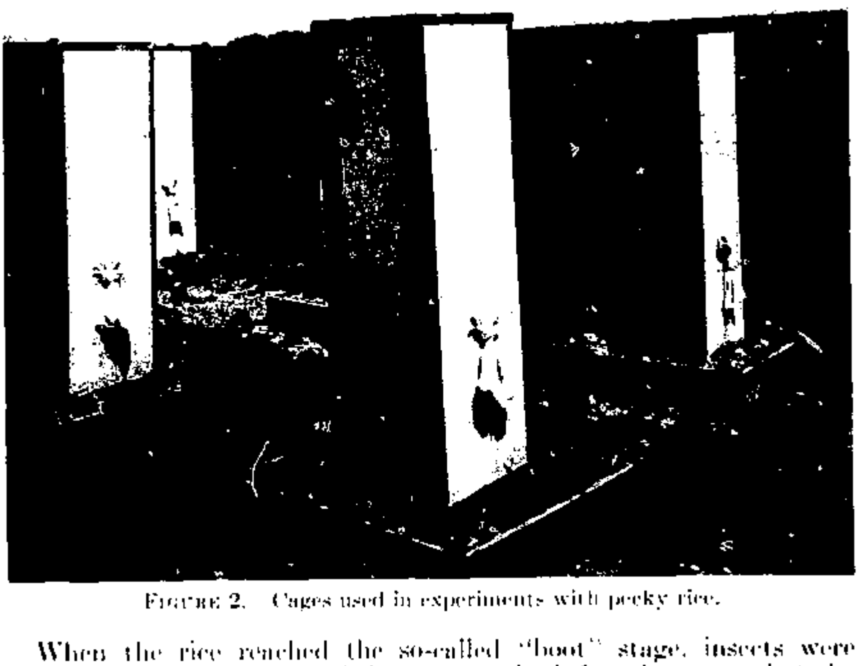

FIGURE 2.—Cages used in experiments with pecky rice.

When the rice reached the so-called "boot" stage, insects were released in triplicate sets of the cages to be infested, except that the cages enclosed with 30-mesh copper were run in duplicate through the experiments. The boot stage is reached a short time prior to the emergence of the panicles from the leaf sheaths, and is noticeable because the flag (top) leaf usually droops and the upper part of the shoot is swollen. The introduced insects were allowed to feed on the rice until it reached maturity, which was approximately 30 days after the panicles emerged.

Culture of Fungi

When the rice matured, the cages were removed and the rice was cut by hand and placed inside the laboratory until it was dry enough to thresh. It was threshed by hand and sterile florets were counted and discarded. Filled kernels were weighed and later removed from the glumes by a Smith shelling device, which removed the hulls under controlled and uniform conditions. The kernels were graded according to the system used by the Federal Rice Supervision and Federal-State Inspection Service of the Grain Branch, U. S. Production and Marketing Administration. The pecky kernels were then separated from the clean ones and were divided into the three classes according to type, after which the kernels of each type were surface-sterilized in a mercuric chloride solution (1:1,000) for 1 minute, then washed in sterile water, and plated on cornmeal-agar or on water-agar. After 10 days or 2 weeks the fungus colonies that had developed were identified and the results were tabulated.

The causal fungi from rice kernels and from spots on green leaves were also identified from tissue platings, and cultures were made from the legs and beaks of stink bugs to see whether spores of the fungi found on the rice plants might have been carried by the bugs.

ENTOMOLOGICAL INVESTIGATIONS

Cage Infestations

SOLUBEA PUGNAX (F.)

From 2 to 14 stink bugs were placed in each cage and were allowed to feed on the developing grains of the rice plants growing in the cage, as previously described. During the years 1933–37 the numbers of stink bugs bred in the cages ranged from a few to over a hundred, but in 1938 a constant infestation was maintained by removing all stages of the insects every 14 days and reinfesting the cages with bugs collected from commercial fields.

The percentage of pecky rice found in the cages ranged from 5 where 2 stink bugs fed in one cage to 76 where 14 fed in a cage (table 1). The severity of kernel discoloration was also proportionately greater in cages with high infestations. The average number of pecky kernels for infested cages was 306 and for the control cages, 76. The actual weight of matured grain was reduced from an average of 57 grams in the controls to 39 grams in the cages with large stink bug populations. The rice harvested from cages with large numbers of bugs was often ground to powder when shelled in the Smith shelling device, because the infested kernels were so severely damaged that they were chalky and soft.

Several sets of cages were infested with fourth- and fifth-stage nymphs. In these cages the pecky kernels ranged from 6 percent in 1937 to 40 percent in 1935. The nymphs fed on the developing kernels, but the percentage of pecky rice in nymph-infested cages was much more variable than in cages infested with adult bugs.

TABLE 1.—*Effects of insects on rice florets and kernels in cage experiments at Crowley, La., 1934–38*

Insect infestation	Year	Florets: Total	Florets: Sterile	Kernels: Total	Kernels: Pecky[1]: D	Kernels: Pecky[1]: O	Kernels: Pecky[1]: L	Kernels: Pecky[1]: Total	Total sterile florets and pecky kernels	
		Number	*Percent*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Number*	*Percent*[2]
SOLUBEA PUGNAX (F.)										
6 fifth-stage nymphs	1934	6, 847	24	5, 231				22	2, 791	41
	1935	6, 215	34	4, 035	161	1, 467	18	40	3, 766	61
	1936	10, 227	24	7, 803	367	530	36	12	3, 357	33
10 fourth-stage nymphs	1937	11, 006	23	8, 428	169	321	40	6	3, 108	28
	1938	8, 896	29	6, 355	231	285	6	8	3, 063	34
1 pair of adults	1934	6, 659	19	5, 402				14	2, 039	31
	1935	4, 790	50	2, 394	223	938	2	49	3, 559	74
	1936	8, 413	23	6, 487	743	174	14	14	2, 857	34
	1937	9, 920	35	6, 469	280	26	20	5	3, 777	38
	1938	9, 332	13	8, 091	303	180	5	6	1, 729	19
3 pairs of adults	1934	5, 801	29	4, 119				33	3, 029	52
	1935	6, 559	38	4, 064	173	1, 230	18	35	3, 916	60
	1936	7, 192	49	3, 673	554	345	23	25	4, 441	62
	1937	8, 199	78	1, 834	66	286	1	19	6, 718	82
5 pairs of adults	1934	6, 776	44	3, 819				69	5, 585	82
	1935	5, 934	75	1, 503	114	751	3	58	5, 299	89
	1936	7, 638	52	3, 657	377	643	46	29	5, 047	66
	1937	10, 726	34	7, 048	295	621	22	13	4, 616	43
	1938	7, 237	39	4, 400	97	1, 335	12	33	4, 281	59
7 pairs of adults	1934	5, 808	34	3, 858				76	4, 882	84
	1935	5, 781	56	2, 521	158	1, 351	4	60	4, 773	83
	1936	6, 832	71	1, 971	373	569	20	49	5, 823	85
3 pairs of adults in cloth field cages	1936	7, 024	71	2, 041	479	439	16	46	5, 917	84
	1938	3, 481	72	972	81	418	2	52	3, 010	86
HAPLOTHRIPS GRAMINIS Hood										
500 in cloth cages	1936	2, 159	23	1, 672	21	5	5	2	518	24
300 in cloth cages	1937	7, 327	39	4, 502	68	95	11	4	2, 999	41
100 in cloth cages	1938	6, 475	17	5, 380	39	63	7	2	1, 204	19

THAMNOTETTIX NIGRIFRONS Forbes											
100 in cloth cages	1936	4, 136	24	3, 134	164	3	8	6	1, 177	28
150 in cloth cages	1937	7, 194	39	4, 360	43	67	8	3	2, 952	41
50 in cloth cages	1938	6, 141	27	4, 491	80	5	1	2	1, 736	28
PAROMIUS LONGULUS (Dall.)											
50 in 30-mesh copper-screen cage	1937	9, 356	36	6, 000	84	474	42	10	3, 956	42
	1938	10, 530	26	7, 752	137	530	23	9	3, 468	33
CONTROL											
None in cages not screened	1934	5, 655	23	4, 338				16	2, 013	36
	1935	7, 887	26	5, 873	172	388	6	10	2, 580	33
	1936	4, 294	25	3, 227	261	22	16	9	1, 366	32
	1937	10, 034	38	6, 189	206	49	8	4	4, 108	41
	1938	8, 793	15	7, 517	144	48	4	3	1, 472	17
None in 18-mesh screen cage	1934	6, 332	19	5, 133				7	1, 548	24
	1935	6, 000	23	4, 600	261	537	8	18	2, 206	37
	1936	10, 011	15	8, 522	203	42	28	3	1, 762	18
None in 30-mesh copper-screen cage	1935	3, 358	11	2, 975	107	14	4	4	508	15
	1936	5, 784	16	4, 867	247	28	10	6	1, 202	21
	1937	5, 766	13	4, 997	90	14	7	2	880	15
	1938	4, 425	6	4, 153	16	0	3	1	291	7
None in cloth cage in field	1936	8, 567	28	6, 130	186	6	19	3	2, 648	31
	1937	13, 435	63	4, 930	152	26	2	4	8, 685	65
Open field, natural infestation	1936	2, 769	23	2, 144	118	21	2	7	766	28
	1937	4, 544	13	3, 957	74	28	8	3	697	15
	1938	5, 780	16	4, 848	74	12	33	2	1, 051	18
Cloth cage, natural infestation	1936	4, 671	21	3, 677	104	43	8	4	1, 149	24
	1937	10, 543	28	7, 566	62	34	9	1	3, 082	29
None in 2 layers of 18-mesh screen around panicles	1937	10, 580	24	8, 006	110	60	13	2	2, 757	26
Field 18-mesh screen	1938	2, 136	44	1, 198	17	0	17	3	972	45
Cloth and cellulose-coated screen	1938	6, 300	14	5, 433	69	12	3	2	951	15

[1] D=discolored; O=circular stigmonose injury by insects; L=linear black discoloration probably mechanical injury to glume. In 1934 the pecky kernels were not so classified.

[2] Percent of total florets.

Kernels from which stink bugs have sucked practically all the contents never develop into millable rice, and the losses are severe. In this paper the kernels thus injured are classed as sterile. When rice kernels develop normally, they become heavy and cause the panicle to droop. As it emerges from the boot the panicle is erect, but, as the kernels mature, it gradually bends over and the branches tend to separate. The effects of the feeding of varying numbers of stink bugs on the kernels are shown in figure 3, in which it may be seen that the

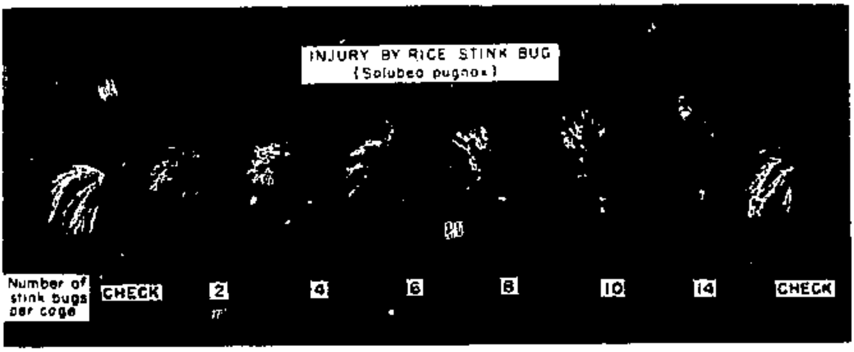

FIGURE 3. Effect of varying numbers of stink bugs on the production of rice grain.

panicles were lighter and more erect when fewer stink bugs were confined on them. Each bundle of rice in the illustration is the entire growth from a single cage of 50 plants.

The sterility ranged from 77 percent in heavily infested cages to 6 percent in the control cages. The average sterility in these experiments for noncaged controls was 26 percent. In only six cases did the percentage of sterility fall below this in any of the stink-bug-infested cages. The sterility averaged 11 percent in 1935-38 in the 30-mesh copper-screen cages, whereas in adjacent unscreened check cages in the same years it was 25 percent. However, when cages were placed in rice fields, sterility was higher in the screen and in the cloth cages than in the nonscreened checks.

OTHER INSECTS

A small sucking insect, *Paromius longulus* (Dall.), was caged with rice in 1937 and 1938. In 1937 the percentage of pecky kernels in a cage containing 50 of these insects was 10, as compared with 2 percent in 30-mesh copper-screen uninfested cages. In 1938 the percentage of pecky kernels in a cage containing 50 insects was 8 percent, as compared with 1 percent in the control cages. As shown in figure 1, *B*, the type of kernel injury is almost identical with that caused by *Solubea pugnax*, the main difference being that the lesions on the kernels are smaller and more nearly round. *P. longulus* caused an increase of 27 percent in sterility in 1937 and 20 percent in 1938.

From 100 to 500 *Haplothrips graminis* Hood were released on rice grown in cloth and cellulose-coated screen cages. There was no significant increase in pecky kernels or in sterile florets. From 50 to 150 leafhoppers, *Thamnotettix nigrifrons* Forbes, were released in the same type of cages and caused no significant additional injury to kernels.

Field Observations

Stink bug populations in Louisiana and Texas rice fields were also studied in relation to the occurrence of pecky rice and fungus diseases. Populations per acre were estimated from the number of bugs caught in 400 net sweeps, covering about one-twelfth acre in each field. Rice kernels were collected in fields that had reached the late dough stage and were cultured for disease organisms. Matured rice was also collected from some fields, and cultures were made from the pecky kernels.

The highest estimated average stink bug population for any one year was 2,430 bugs per acre. The maximum estimated population in any one field was 18,446 per acre in a field near Katy, Tex. The average population count made in Texas for fields in which the rice was in the milk and dough stages was 1,214 bugs per acre. The average stink bug populations per acre in Texas were 1,065 in 1934; 683 in 1935; 582 in 1936; 2,461 in 1937; and 1,277 in 1938.

These insects apparently are attracted into the rice fields when the panicles begin to emerge. To determine the distribution of stink bug populations and injury within fields, six representative fields of Blue Rose rice in the same stage of growth were studied each year from 1935 to 1938, inclusive, in the vicinity of Crowley, La. For each field the numbers and stages of stink bugs in 200 net sweeps per half-acre on the levee adjacent to the field, within the field but near the levee, and in the center of the field were recorded at 3-day intervals from the time the panicles emerged until they matured.

Table 2.—*Average stink bug populations per acre at 3-day intervals from emergence of panicles to their maturity at different locations in or adjoining 6 fields of Blue Rose rice near Crowley, La., 1935–38*

Interval (days)	On levee adjacent to field	Within the field	
		Near levee	In center
0	638	932	764
3	584	1,144	1,032
6	608	1,620	1,372
9	632	1,360	1,384
12	680	1,620	1,552
15	604	1,500	1,412
18	620	1,388	1,180
21	480	920	900
24	604	1,036	864

As shown in table 2, there were no pronounced changes in stink bug abundance during that period on the levees adjacent to the fields. Within the fields, however, the populations varied with the stage of maturity of the rice, increasing until about the twelfth day, when the kernels reached the dough stage, and decreasing thereafter.

The population in the fields was heavier near the levee than in the center when the stink bugs were entering the fields during the first 6 days after the panicles began to form, and again when the stink bugs began to leave as the rice became more mature. The sterility caused by stink bugs was much higher near the levee than in the center of the fields, because of the larger population at the levee soon after panicle emergence. The rice was then in the milk stage and the entire contents was sucked out.

Stink bug populations varied widely from year to year, both outside and inside the fields, as shown in table 3. The average stink bug populations per acre for the season were calculated from the sweep-net records, and the proportions of pecky rice near the levee and in the center of each field were determined. The percentage of pecky kernels, in general, increased as the number of stink bugs increased in the field, both near the levee and in the center.

TABLE 3.—*Average annual stink bug populations per acre at different locations in or adjoining 6 fields of Blue Rose rice and average percentage of pecky kernels near edge and in center of the fields, Crowley, La.*

Year	Number of stink bugs			Percent of pecky kernels	
	On levee adjacent to field	Within the field		Near levee within field	In center of field
		Near levee	In center		
1935	826	711	806	1	1
1936	866	2,411	1,841	8	4
1937	491	1,081	1,150	3	2
1938	364	789	646	4	1
Average	637	1,248	1,111	4	2

At the time these investigations were conducted the only means of controlling damage from these insects was by planting long, slender-grained varieties, which have been shown to be less severely affected than the medium- and short-grained varieties, such as Blue Rose. Insecticides now available offer a possible solution of this insect-control problem. The data obtained by the present writers indicate the need for further investigation into the insecticidal control of pecky rice. Presumably, the types of rice preferred by the stink bugs will continue to be grown in some sections of the area where the bugs are abundant.

PATHOLOGICAL INVESTIGATIONS

During the preliminary investigations it seemed desirable to determine whether the rice stink bug might be responsible for some of the spread of fungi cultured from the pecky kernels. A determination of the fungi causing the leaf spots was made by leaf-tissue platings, and then the legs and beaks of some of the stink bugs were collected and plated. Since it was desired to determine whether or not the spores were carried by the bugs, the legs and beaks were not surface-sterilized. The results of these platings are shown in table 4.

TABLE 4.—*Numbers of fungi isolated from rice leaf spots and from beaks and legs of stink bugs, 1934–35*

Fungi isolated	From leaf spots	From stink bugs
Helminthosporium oryzae van Breda de Haan	79	0
Cercospora oryzae Miy	4	0
Nigrospora oryzae (Berk. & Br.) Petch	18	22
Curvularia lunata (Wakker) Boedijn	2	18
Cladosporium herbarum Link ex Fr.	0	26
Fusarium spp	0	17
Phoma spp	23	11
Helminthosporium sp	8	0
Alternaria sp	0	1
Oidium sp	0	11
Penicillium sp	0	15
No fungi obtained	3	29
Total	137	150

Immature kernels fed on by stink bugs were surface-sterilized and plated on water-agar. No fungus developed on 30 percent of the kernels, *Helminthosporium oryzae* developed on 30 percent, *Fusarium* spp. on 20 percent, and *Curvularia lunata*, *Phoma* spp., and *Aspergillus* spp. on the remaining 20 percent. From tissue platings of glume spots in the immediate vicinity from which the above-mentioned species were found, *H. oryzae* developed from 40 percent, *C. lunata* from 12 percent, and *Phoma* spp. and *Nigrospora oryzae* from 14 percent. The remaining 34 percent produced no fungus. The kernels that had been attacked ranged in size from "shoe peg" to fully formed grains.

These results show that, at the times when the platings were made, it might have been possible for the stink bugs to carry the spores of *Nigrospora oryzae*, *Curvularia lunata*, and *Phoma* spp. and thus spread these fungi. However, *Phoma* spp. is the only one that is very likely to have initiated infection on the leaves or glumes, as the first two are largely secondary in nature and are found on dead leaf tips or on old spots that had been produced by *Helminthosporium oryzae*. It is of interest that neither *H. oryzae* nor *Cercospora oryzae*, the two most important and widespread leaf spot fungi, were isolated from the bugs, even though considerable spotting caused by both these fungi was found on the rice at the time the platings were made.

Six lots of rice containing pecky kernels were received from Galveston, Tex., in 1934, and the pecky kernels were separated and cultured. The results are given in table 5. Most of the fungi cultured from these lots were *Curvularia lunata*, *Helminthosporium oryzae* and *Trichoconis caudata* (Appel and Strunk) Clements.

TABLE 5.—*Fungi cultured from pecky rice received from a Texas rice-milling company in 1934*

Kind of rice and type of injury	Number of kernels with—							
	No fungi	*Curvularia lunata*	*Helminthosporium oryzae*	*Fusarium* spp.	*Trichoconis caudata*	*Phoma* spp.	*Cladosporium herbarum*	Other fungi
Polished:								
O	3	1	2		1			1
L	4	3	1		2			
D	2	21	2		1			
Slightly D	3	5	5		1			
Sclerotioid bodies [1]								
Brown:								
O	5	1	8	1	10			
L		2	7		5			
D		11	4		4			
Slightly D	7	4	20		3			
Sclerotioid bodies		25	2	1	24			
Polished:								
O	13	3	0	1	4			2
D		13						
Slightly D	12	7	1		6		1	1
Brown:								
O	35	19	8	9	39	4	11	5
L		3	2		1			
D	13	36	13	1	20	1	3	
Slightly D	3	2						
Sclerotioid bodies		70	1	2	2			
Polished:								
O	74	9	6	3	9		3	5
L	15	2	2		2			
D	2	16	2		1			1
Slightly D	6	14	3		1		1	
Polished:								
O	13		2	1				
L	2	2	2					
D	1							
Slightly D	40	26						1
Sclerotioid bodies		2						

[1] These kernels were not discolored, but small, black sclerotioid bodies were present just under the kernel coat. All were removed in the milling process.

In addition to the platings referred to above, platings of pecky kernels from different sources were made in 1933 and 1934. The summarized results of these platings are given in table 6. In the samples from Beaumont, Tex., in all three types of kernel injury, distinctly higher percentages carried fungi in 1934 than in 1933. The leaf spotting caused by *Helminthosporium oryzae* was also more severe in Texas in 1934 than in 1933.

In 1934 and 1935 isolations were made from all pecky kernels in the cage experiments at Crowley, La., and from 1936 through 1938 from 10 percent of each type of kernel injury. The results of these platings are given in table 7.

Considerable fluctuation occurred in the percentage of fungi found on the plants and grains in the years covered by these experiments. On the basis of total pecky kernels, *Curvularia lunata* reached a peak in 1935 of 16 percent, then dropped to 11 percent in 1936 and to 10 percent in 1937, but increased to 13 percent in 1938. *Helminthosporium oryzae* in 1937 caused more than twice as much injury as the 2 percent maximum in 1934–36, and then dropped to 4 percent in 1938. *Trichoconis caudata* increased from 11 percent in 1934 to 13 percent in 1935, then dropped to 7 percent in 1936, and increased again to 9 percent in 1937 and 14 percent in 1938. *Phoma* spp. dropped from a high of 14 percent in 1934 to 5 percent in 1935, to 4 percent in 1936, and to 3 percent in 1937, but increased to 6 percent in 1938. *Fusarium* spp. ranged from 12 to 21 percent; but, inasmuch as these fungi do not cause discoloration, they are of no particular interest here. With the exception of the *Penicillium* spp. in 1936 and *Epicoccum neglectum* Desm. in 1935, none of the other minor fungi listed here were abundant enough to be significant.

The averages for the 5 years show that the discolored group, which is the group largely produced by fungus attack, constituted the largest percentage of kernels from which fungi developed, followed by the 0 group, with the L group lowest.

Of the species that cause discoloration, *Curvularia lunata*, *Trichoconis caudata*, and *Fusarium* spp. were most often cultured from the discolored kernels; *Helminthosporium oryzae*, *Fusarium* spp., *Phoma* spp., *T. caudata*, and *C. lunata* from the L type; and *Phoma* spp., *T. caudata*, *Fusarium* spp., and *C. lunata* from the pecky kernels. There was a variation of only 4 percent for *Fusarium*, and the other fungi were present in so few kernels that they were not considered important during the period covered by these investigations.

TABLE 6.—*Fungi isolated from pecky rice received from Arkansas, Louisiana, and Texas*

Source	Year	Type of kernel injury	Total number of kernels	Percent of kernels with—							
				No fungi	*Curvularia lunata*	*Helminthosporium oryzae*	*Fusarium* spp.	*Trichoconis caudata*	*Phoma* spp.	Other fungi	All fungi
Stuttgart, Ark	1934	O	388	83	2	5	1	1	3	5	17
Crowley, La	1934	O	748	46	5	6	11	22	6	7	52
Beaumont, Tex	1933	O	488	90	1	6	0	1	0	2	9
	1934	O	201	23	11	34	10	16	2	1	77
Stuttgart, Ark	1934	L	287	74	5	8	2	1	1	7	25
Crowley, La	1934	L	180	56	2	15	8	12	4	2	44
Beaumont, Tex	1933	L	336	75	1	21	0	0	0	3	24
	1934	L	118	32	3	48	7	9	0	0	68
Stuttgart, Ark	1934	D	274	60	15	14	1	2	3	5	39
Crowley, La	1934	D	317	20	14	20	14	25	6	1	80
Beaumont, Tex	1933	D	69	64	0	16	1	0	0	19	36
	1934	D	665	18	10	44	7	18	2	1	82

In 1938, in addition to the introduction of bugs into the cages, some of the rice in the cages was sprayed at flowering time with a mixture of *Helminthosporium oryzae* and *Curvularia lunata*. This treatment increased the number of kernels in the discolored group (table 8). The number of discolored kernels per cage increased from an average of 81 in control (noninoculated) rice to 129 in inoculated but not bug-infested lots. The average number of discolored kernels for inoculated and bug-infested lots was 127, and for bug-infested lots alone it was 132.

The results of platings of approximately 10 percent of the kernels representing each type of kernel injury are given in table 9. A significantly larger number of discolored and pecky kernels from the inoculated lots produced *Helminthosporium oryzae* and *Curvularia lunata* than did the kernels from the controls. Apparently the inoculations with the fungus produced infestation of a much larger number of the kernels than is normal.

A comparison of the percentage figures for the 5-year average, with 1 year's results from lots inoculated with *Helminthosporium oryzae* and *Curvularia lunata*, shows that, as a result of inoculation in the pecky group, *C. lunata* was isolated from about twice as many kernels and *H. oryzae* from three times as many kernels as the 5-year average; in the discolored group *C. lunata* was isolated from about 5 percent fewer kernels, but *H. oryzae* was isolated from over six times as many kernels; in the L group *C. lunata* was isolated from nearly three times as many kernels as the 5-year average, and *H. oryzae* from a somewhat smaller number.

TABLE 7.—*Pecky rice found carrying fungi in cage experiments at Crowley, La., summary for 1934–38*

O (CIRCULAR TYPE) INJURY

Year	Number of kernels plated	Percent of kernels with—[1]													
		No fungi	*Alternaria* sp.	*Aspergillus niger* v. Tiegh.	*Cladosporium herbarum*	*Curvularia lunata*	*Epicoccum neglectum*	*Fusarium* sp.	*Helminthosporium oryzae*	*Nigrospora oryzae*	*Penicillium* spp.	*Phoma* sp.	*Podoconis* sp.	*Trichoconis caudata*
1934	4, 359	41	1	0	3	14	0	35	3	1	1	24	0	18
1935	2, 669	48	2	2	2	26	6	21	4	1	1	11	1	22
1936	676	45	3	3	1	19	2	26	1	1	26	6	1	10
1937	689	54	1	1	1	21	3	34	10	2	1	5	0	21
1938	258	48	2	0	4	20	4	24	6	1	0	16	0	22
Total or average	8, 651	47	2	1	2	20	3	28	5	1	5	12	0	19

D (DISCOLORED TYPE) INJURY

1934	314	24	0	0	1	15	0	29	8	0	1	25	0	21
1935	1,284	37	2	2	1	32	2	22	3	1	1	7	0	26
1936	594	46	2	1	0	24	1	35	5	1	5	8	1	15
1937	593	78	1	1	1	20	1	30	24	1	1	6	0	16
1938	174	44	0	0	0	30	0	20	8	1	0	3	0	37
Total or average	2,959	46	1	1	1	24	1	27	10	1	1	10	0	23

L (LINEAR TYPE) INJURY

1934	44	20	19	0	0	4	0	21	14	0	0	21	0	21
1935	205	54	2	0	0	24	5	34	10	1	0	7	0	15
1936	55	51	7	0	26	7	4	26	7	0	0	0	0	22
1937	55	75	0	0	0	21	0	21	21	0	0	7	0	28
1938	15	87	0	0	0	0	0	0	50	0	0	50	0	0
Total or average	374	57	6	0	5	11	2	20	20	1	0	17	0	17

[1] Based on the total number of kernels with fungi, rather than on the number of kernels plated.

TABLE 8.—*Average amount of pecky rice of different types and clean rice per cage after artificial inoculation of Blue Rose rice with Helminthosporium oryzae and Curvularia lunata at flowering time, in conjunction with stink bug infestation at Crowley, La., and Beaumont, Tex., in 1938*

Treatment	Cages	Pecky kernels						Clean kernels		Pecky and clean broken kernels
		D type	O type	L type	Total					
	Number	*Number*	*Number*	*Number*	*Number*	*Grams*	*Percent*	*Number*	*Grams*	*Grams*
Inoculated only	3	129	0	22	151	3	4	3, 240	65	10
Inoculated, then infested	3	127	284	30	441	9	17	2, 070	41	9
Infested, then inoculated	2	138	769	24	931	18	41	1, 367	28	21
Infested only	4	132	520	42	694	14	31	1, 536	30	15
Controls	2	81	10	16	108	2	3	3, 450	70	12

TABLE 9.—*Pecky kernels of Blue Rose rice from which fungi were isolated in cage experiments at Beaumont, Tex., and Crowley, La.*

Fungus isolated from kernels	Fungus then stink bug (O type)		Stink bug then fungus (L type)		Fungus only (D type)		Control	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Curvularia lunata	61	36	6	30	24	19	13	16
Helminthosporium oryzae	30	17	3	15	82	61	4	5
Trichoconis caudata	31	20	6	30	12	10	6	8
Phoma spp.	3	3	0	0	0	0	2	2
Fusarium, white	22	14	5	25	5	4	9	11
Fusarium, pink	8	6	0	0	1	1	0	0
Cladosporium herbarum	1	2	0	0	0	0	1	1
Aspergillus terreus Thom	0	0	0	0	8	6	0	0
Epicoccum neglectum	2	1	0	0	0	0	1	1
Nigrospora oryzae	2	1	0	0	0	0	0	0
Mucor sp.	1	1	0	0	0	0	0	0
Kernels:								
With fungus	157		20		132		38	
Without fungus	230		15		32		44	
Total	387		35		164		82	

SUMMARY

Rice kernels bearing spots are known to the trade as pecky rice. This condition causes considerable loss to rice growers and millers, and investigations were carried out to determine the relative importance of insects and fungi in the production of pecky rice. The pecky kernels were found to be due to injuries by stink bugs or disease organisms. Three types of spots were common: Discolorations (D type), circular stigmonose injury by insects (O type), and linear black discolorations, probably mechanical injury to the glume (L type).

When caged on growing rice while the panicles were developing and maturing, the rice stink bug (*Solubea pugnax* (F.)) and the sucking bug *Paromius longulus* (Dall.) were found to increase greatly the percentage of sterile or empty glumes. In cages heavily infested by the rice stink bug sterility reached 78 percent, as compared with 6 percent in uninfested cages. Fifty *Paromius* bugs per cage increased the sterility over 20 percent.

In cage experiments an increase in infestation by the rice stink bug and by the sucking bug increased the percentage of pecky rice. The largest increases of pecky rice accompany increases in both insect populations and leaf spot fungi. In all cages in which either the rice stink bug or the sucking bug was used, the number of pecky kernels with circular stigmonose injury (O type) exceeded the number of discolored kernels, except in the cages containing the following insects: (1) 2 adult stink bugs, (2) 6 adult stink bugs, (3) 500 thrips, and (4) 100 leafhoppers in 1936; 2 adult stink bugs in 1937; (1) 2 adult stink bugs and (2) 50 leafhoppers in 1938. The plants in these cages were inoculated with *Helminthosporium oryzae* van Breda de Haan and *Curvularia lunata* (Wakker) Boedijn in 1938. In the control lots the number of discolored kernels exceeded the O type in the following cages: 30-mesh copper-screen in 1935; both screened and unscreened controls in 1936, 1937, and 1938.

Fungi were cultured from 46 percent of the kernels with the O type injury and from 59 percent of the discolored kernels.

The fungi most frequently associated with the pecky condition in rice were *Curvularia lunata*, *Fusarium* spp., *Phoma* spp., *Trichoconis caudata* (Appel & Strunk) Clements, and *Helminthosporium oryzae*. Artificial inoculation with *H. oryzae* and *C. lunata* in 1938 caused a marked increase in percentage of kernels attacked by these two fungi.

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