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Black Kernel and White Tip of Rice

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

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Black kernel and white tip of rice are common troubles causing losses to rice growers each year. Laboratory and field experiments indicate that black kernel can be reduced by preventing heating of rice in stacks and in storage, and by the elimination of old rice straw and other organic material upon which the fungus lives from season to season.

White tip appears to be due to a lack of balance between magnesium and calcium in the soil. Trials on a small scale to determine the needs of a particular soil are suggested.

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BLACK KERNEL AND WHITE TIP OF RICE

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In Texas, the rice-producing area of some 255,000 acres, occupies a strip of coastal land about 50 miles wide and 240 miles long extending from Jackson County to Louisiana. This acreage produces approximately one-fourth of the United States rice crop, or about $9,000,000 annually for Texas.

Rice is relatively free from such devastating diseases as the rusts of other cereal crops. There are, however, several diseases and disorders which affect rice in a less striking fashion and which are important factors in successful production. Among the diseases common to rice in Texas, black kernel and white tip cause appreciable losses, varying from one-tenth to 1 per cent of the total value of the crop each year. The control of these diseases is of interest to every rice grower. It was through the efforts of some of the leading growers in the Texas area that a state appropriation was obtained in 1937 for the investigation of black kernel and other diseases of rice. This paper is one of the first publications on the results of this work.

THE BLACK KERNEL DISEASE

During the past few years much of the rice produced in the Gulf Coast area has been of inferior quality because of the occurrence of an occasional jet black grain in the polished product. These discolored kernels, which do not show up until after milling, must be removed by hand before the rice can be marketed as fancy quality. Millers in the areas where the black kernel disease is serious state that whenever it is discovered in a crop the value is reduced 25 to 50 cents a sack (162 lb.) owing to the expense of removing the discolored grains. Figure 1 shows the appearance of these black kernels and illustrates how conspicuously they stand out in a sample of polished rice.

The black kernel disease was first reported in 1935 by Taubenhaus, Altstatt, and Wyche (6) when the seriousness of the disease was noted and certain organisms were isolated from the discolored kernels. These investigators continued their work (5), (7), through 1935, 1936, and 1937 and found that the disease could be observed in practically all commercial varieties of rice. Inspection of 15 of the more common varieties, as shown in Table 1, indicated that the percentage of wholly black grains varied from 0.04 per cent in a sample of Rexoro to 1.1 per cent black kernals in

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a sample of Caloro; other varieties showed percentages of infection intermediate between these figures. Rice collected during the 1938 season indicated that the Fortuna and Shoemed varieties were most severely affected that year, while traces of the disease were present in Rexoro, Lady Wright, Blue Rose, Caloro, Delitus, and Early Prolific. These samples were collected throughout the Texas rice-growing area and the greatest number of infected samples was found in the regions of Katy and Eagle Lake.

Black Kernel Caused by a Fungus

Investigations on discolored rice grains by different workers (7), (8) indicated that black grains which retained their identity through the milling process were most frequently infected with a fungus known as

Table 1. Prevalence of discolored and totally black kernels in different varieties of rice grown at the Beaumont Station during 1935

Variety	Number kernels examined	Discolored kernels, per cent		
		Light	Medium	Black
Acadia	1733	1.8	4.8	0.7
Caloro	1778	1.7	6.0	1.1
Colusa	1829	3.1	7.5	1.2
Delitus	2375	1.0	2.5	0.1
Early Prolific	1846	1.3	3.8	0.3
Edith	1622	2.2	4.3	0.5
Fortuna	1519	1.3	1.4	0.5
Honduras	1588	1.6	2.4	0.4
L. W. 10	1631	0.7	2.6	0.2
Iola	1764	1.1	1.5	0.1
Nira	1510	1.4	2.9	0.3
Rexoro	2196	0.7	0.7	0.04
Shoemed	1702	1.8	0.5	0.1
Storm Proof	1962	0.8	2.1	0.2
Supreme Blue Rose	1788	1.3	3.3	0.4

Curvularia lunata. Several other fungi were frequently found associated with black grains but the grains in these cases were usually chalky and had a tendency to disintegrate upon milling. In our work also, *Curvularia lunata* has been found to occur in from 40 to 80 per cent of the black grains varying with the location from which the sample was taken.

More recently, the senior author has worked with the Shoemed variety from the 1937 crop and with Fortuna variety from the 1938 crop. Samples of these were hand milled by rubbing the rough rice on a corrugated board with a pig-skin-covered block. The discolored kernels were then sorted out and disinfected on the surface by immersing for 5 minutes in a 1-1000 solution of bichloride of mercury followed by a thorough washing in distilled water. The seeds were then placed on a 1 per cent non-nutrient agar and kept in an incubator at 35° C. for one week. Table 2 shows the occurrence of the most prevalent types of fungi observed in these cultures.

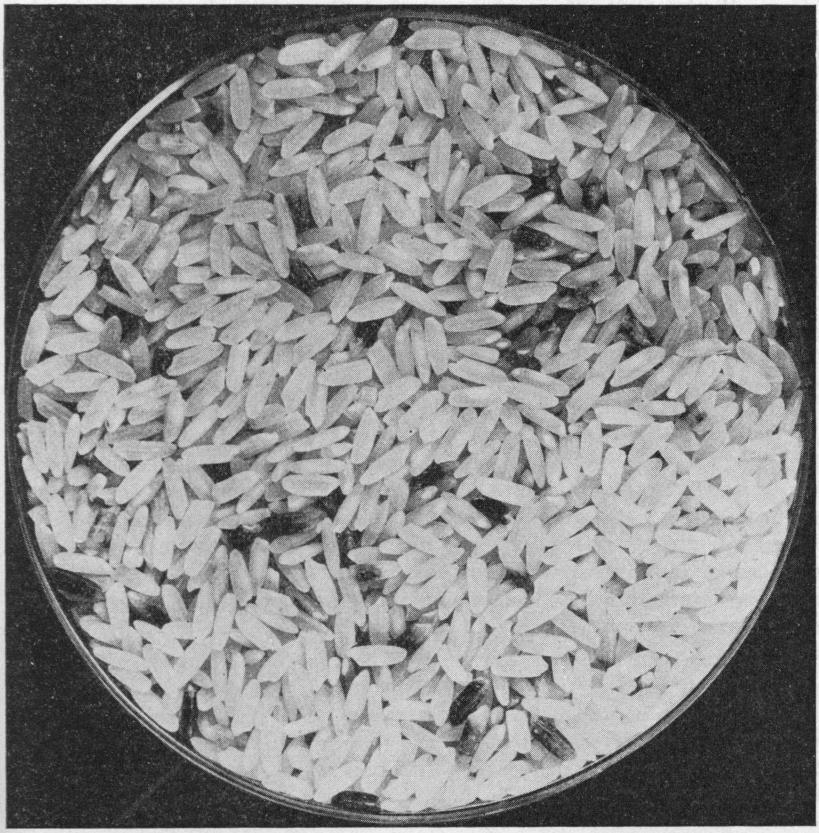

Fig. 1. Black kernels in a sample of polished rice.

Table 2. Fungi isolated in 1938 from black kernels of rice which had been surface sterilized and cultured on non-nutrient agar

Variety	Number of kernels cultured	Percentage of kernels showing infection								
		Curvularia lunata	*Helminthosporium oryzae*	*Trichoconis caudata*	*Penicillium spp.*	*Rhizopus spp.*	*Alternaria spp.*	*Basisporium gallarum*	*Fusarium spp.*	Unidentified
Fortuna	600	30.1	2.1	4.3	10.1	5.3	0.7	0	0.01	13.5
Shoemed	1200	28.9	8.2	1.2	7.2	11.0	0	0.03	1.0	23.5

From these results it can be seen that *Curvularia lunata* was by far the most common fungous organism obtained from the black grains. *Helminthosporium oryzae* and *Alternaria sp.* also produce black kernels, but these organisms have a tendency to cause the grains to become soft and chalky so that they disintegrate upon milling and consequently are not present in polished rice. *Trichoconis caudata* causes small black specks on the grains but these are usually rubbed off in the milling process. *Curvularia lunata* was the only organism recovered from these grains which was capable of discoloring the entire kernel without destroying its hard, grain-like structure.

Infection Takes Place in the Flower

The prevalence of *Curvularia lunata* infections on the discolored seeds led to a study of the effects of this fungus when placed on growing plants. The pulverized black kernels as well as spores from pure cultures of *C. lunata* were used to inoculate different series of plants at different times during the period from seed to milling. In some cases the spores were injected into the plants with a hypodermic syringe, other plants were sprayed or dipped with an aqueous spore suspension, and still others were dusted with pulverized black kernels. Treatments were made by the senior author every two weeks during the growing period. Table 3 shows the effects of these treatments on the prevalence of black kernels among the mature grains.

The fungus causing black kernel does not produce a systemic infection in the plant. That is, unlike certain smuts of cereal crops, the fungus does not become established in the stem or leaves before showing up in the grain. When pulverized black kernels were placed in the soil with the seeds there was no evidence of any infection in the crop. Stem injections and spraying treatments made with spore suspensions had no effect on the seeds produced. However, when the blossoming rice heads were dipped

Table 3. Effects of inoculation, at various stages of development of the rice plant, upon the number of black kernels at maturity

Method of inoculating	Inoculum used	Number of black kernels in 1000 grains at harvest
Seed dusted at planting	Spores	0
Seed dusted at planting	Black kernel powder	0
Growing plants sprayed in field	Spores	0
Growing plants injected in field	Spores	0
Growing plants dusted in field	Black kernel powder	0
Blossoms sprayed in field	Spores	12
Blossoms dipped in water suspension	Spores	13
Blossoms dusted	Black kernel powder	233
Blossoms sprayed and bagged	Spores	172
Blossoms dipped and bagged	Spores	107
Blossoms dipped, bagged, and incubated at 35° C. after harvest	Spores	129
Mature heads sprayed in shock	Spores	0
Mature heads sprayed in shock which were kept damp	Spores	0

or sprayed with a suspension of *C. lunata* spores in water, a large number of the seeds were discolored. Dusting with pulverized black kernels produced even larger numbers of discolored grains than the spore treatments. Possibly the fungus remains viable for longer periods in the rice grain than in the spore stage and so causes infection as the flowers continue to bloom.

Seeds May Become Infected With the Disease But Will Not Become Black Unless They Are Kept Warm and Damp

Practically all samples of polished rice contain kernels which have small discolored spots on them. These "specks" may be black, pink, yellow, or brown in color and vary in size from a tiny dot to three-fourths or more of the kernel. When these kernels are cultured the spots often give rise to various molds and bacteria. The specks are usually caused by bites made by insects while the grain is in the milk stage. Several injuries often are followed by infection with various types of fungi which cause a discoloration. *Curvularia lunata* was frequently obtained in culture from rice grains that have black spots and it was believed that these infections may have been carried by insects. Also, Taubenhaus (5) obtained *Helminthosporium sp.*, *Trichoconis sp.* and *Fusarium sp.* from cultures of insect-injured kernels. During the spring of 1939 Shoemed rice growing in the greenhouse was used for an inoculation experiment in an effort to reproduce conditions which might follow the bites of insects. A suspension of *C. lunata* spores was injected with a hypodermic syringe into some seeds in the milk stage and into others when mature. A few typical black kernels were present when the rice was harvested and every inoculated seed had a minute dark spot caused by the needle puncture. When the seeds which appeared normal except for the puncture spots were surface sterilized with 1:1000 bichloride of mercury solution and cultured on a 1 per cent non-nutrient agar, *C. lunata* developed in nearly every case. Later the seeds became covered with the mycelium and spores of *C. lunata*. Table 4 shows the results of this experiment.

Table 4. Inoculation of immature rice seeds with *C. lunata* as affecting the resulting number of black kernels in the mature heads

Method of inoculation	Condition of kernel	Number of kernels: Inoculated	Maturing	Black at harvest	Black after incubation	Showing *C. lunata* No.	Showing *C. lunata* %
Needle puncture	In bloom	12	6	0	4	6	50
Needle puncture	Bloom—Milk	12	5	0	1	3	25
Needle puncture	Milk	56	34	3	20	32	57
Needle puncture	Milk—Mature	8	8	1	4	8	100
Dipped in spore suspension	Milk	15	10	6	7	10	67
Dipped in spore suspension	Milk—Mature	32	24	0	4	4	13
Dipped in spore suspension	Nearly Mature	31	27	0	7	8	26

The seeds were gathered directly from plants in the greenhouse and were kept free from such dampness and heat as might occur out of doors. Since the humidity is much lower in the greenhouse than in the field, some of the kernels were incubated at 35° C. in a moist chamber. Kernel discolorations were very pronounced after incubation under moist conditions and many seeds became entirely black. More black kernels were obtained from inoculations made during the milk stage than after the seeds had matured. Most insect specks occur during this stage and it is likely that insects in moving from seed to seed carry the *C. lunata* spores and spread infection throughout the field. Many of these infections would not develop into black kernels unless the grain became damp and heated either in the shock or stack.

Table 5. Distribution and frequency of occurrence of fungi in dust from rice straw stacks, as shown by exposed plates

Location	Variety	Number of colonies of fungi most frequently isolated							
		Curvularia lunata	*Penicillium spp.*	*Fusarium spp.*	*Helminthosporium oryzae*	*Trichoconis caudata*	*Rhizopus spp.*	*Alternaria spp.*	Others
Black kernel present in previous rice crop:									
Eagle Lake	Rexoro	2	72	3	0	3	5	3	0
Katy	Nira	7	160	7	18	3	23	0	3
Katy	Lady Wright	0	44	0	0	6	34	0	0
Katy	Lady Wright	6	22	5	0	1	10	5	5
Katy	Early Prolific	0	164	0	0	13	16	0	1
Katy	Lady Wright	2	27	10	0	2	4	0	6
Katy	Lady Wright	2	10	0	3	2	2	2	0
Katy	Lady Wright	3	59	2	5	4	12	0	0
Katy	Unknown	3	3	4	1	12	3	42	20
Stowell	Blue Rose	19	84	18	10	31	0	0	6
Black kernel not present in previous rice crop:									
Alvin	Unknown	0	10	0	0	0	0	0	6
Alvin	Unknown	0	13	0	0	0	0	0	48
Angleton	Unknown	0	43	0	0	1	1	0	43
Angleton	Unknown	0	6	1	0	1	1	0	3
China	Unknown	0	64	1	0	3	2	0	0
East Fannett	Unknown	0	7	0	0	3	4	0	1
Fannett	Unknown	0	6	0	0	2	1	0	49
Katy	Fortuna	0	80	5	0	1	14	0	4
Katy	Blue Rose	0	122	3	1	5	5	0	0
Lissie	Unknown	0	0	15	5	1	0	30	0
Stowell	Blue Rose	1	31	4	4	3	1	5	10
Westberry	Unknown	0	6	0	0	2	3	0	0
Condition of previous rice crop unknown:									
Amelia	Unknown	1	300	4	0	7	1	5	10
Amelia	Unknown	0	70	6	5	10	0	0	0
Amelia	Unknown	0	8	7	14	6	0	31	4
China	Unknown	2	400	20	2	15	0	1	0
Eagle Lake	Unknown	0	2	0	0	2	1	0	1
Eagle Lake	Unknown	0	15	0	0	0	1	0	0
Futche	Unknown	0	350	4	5	8	1	20	1
Katy	Blue Rose	0	3	12	0	23	4	0	2
Lissie	Unknown	1	8	17	5	12	0	23	0
Stowell	Unknown	8	35	4	6	15	3	10	0

Natural Means of Crop Infection

The fungus, *C. lunata*, is extensively distributed and is able to grow on decaying rice straw, weeds, and other organic matter. Since rice straw is kept from year to year as a forage for cattle on many farms, the dust blown from straw stacks may be responsible for spreading the black kernel disease to new crops each year. Petri dishes containing a rice-agar medium were exposed for about 10 seconds to dust stirred up around overwintered rice stacks. In most cases, 5 plates were exposed at each location. The exposed plates were then incubated at 35° C. for six days and observed for fungous colonies. The cultures obtained from stacks of straw, rice from which had yielded black kernels the previous year, almost invariably showed the presence of *C. lunata*. Some of these exposures averaged 4 colonies of this organism per plate while neighboring stacks yielded one and two colonies per exposure. When exposures were made to dust from stacks on farms where the black kernel disease had not occurred only an occasional colony of *C. lunata* was found. In all cases decay-producing fungi were obtained from the exposures as well as several non-pathogenic species. The fungi commonly obtained from these cultures and the number of times they occurred are lisited in Table 5. It is evident from this table that *C. lunata* was more numerous in those cases where the previous crop had been infected with the black kernel disease. It seems probable that *C. lunata* may overwinter in the straw stacks and new infection may result from the spores being blown to the blossoming plants the next season. Dry weather and high winds during the blooming period may increase the amount of infection in the new crop.

Methods of Control

1. With our present knowledge of the black kernel disease, the destruction of all rice straw stacks as soon as threshing is completed is suggested. It probably would be well to burn the straw from the early varieties as soon as the thresher has pulled away from the pile as this straw serves as a source of inoculum for all rice which blooms after this early crop has been harvested. In cases where the straw must be retained as forage for cattle during the winter, it would be well to destroy the unconsumed portion as soon as there is enough green pasturage to supply the needs of the animals in the spring.

2. Weeds and volunteer rice should be cut and burned. Occasionally in the rice fields and along the levees there will be weedy spots in which the plants accumulate, die, and dry up, leaving a mass of debris upon which the Curvularia fungus may grow and fruit, thus supplying spores for infecting the next year's crop. All such accumulations should be burned before another crop of rice is planted.

3. Due to the fact that threshing stirs up fungous spores on the rice, this process is probably responsible for distributing infections from early rice to the later varieties. Should the early rice be threshed while the later varieties are in bloom it is possible that these varieties would have a severe infection of black kernels from the spores distributed from the early rice, which may have been only mildly affected. Whenever possible the early and late varieties should be located on different parts of the farm, preferably some distance apart. In this manner many infections would be avoided.

4. Insect control in rice fields is impossible under present day practices, but, should the value of the crop justify the expense, this problem should be given some consideration. Stink bugs and other insects which move from grain to grain are probably responsible for increasing the number of infections within a given crop.

5. The use of clean seed cannot be too strongly advocated. While black kernel organisms are carried in the seed, no evidence of seedling infection from this source has been obtained. It is possible, however, that seed spilled on levees and roads at planting time may serve as a medium for the growth of the fungus and thus produce spores to infect the new crop.

6. Many rice seeds which have small infected spots following insect punctures will be milled out as perfect grains. However, if these grains are allowed to remain damp and become heated in the shock, or in storage after threshing, the fungus will grow through the grains and cause them to turn black. In order to reduce the number of grains discolored by this method, all shocks should be opened and dried as soon as possible after a rain. Grain should also be thoroughly dry when threshed or dried subsequently so that no heating can occur in the warehouse.

WHITE TIP OF RICE

A condition known as "white tip" is frequently observed in rice fields during the midseason and late growing periods. Mild forms of this disease are characterized by the appearance of white chlorotic areas at the tips of one or more of the new leaves of the plants. In more advanced stages the chlorotic area moves downward, usually involving about half of the leaf, and one-half inch or more of the leaf tip dies and dries up. When the flag leaf is injured the panicle sheath remains very tightly rolled so that the head is compressed as it emerges from the boot. The sheath is frequently so tightly twisted that the head has to force its way through the side. The flowers which are borne on heads that emerge in this manner are often sterile or produce distorted grains, resulting in decreased yields. The photographs in Figure 2 show mild and severe examples of white tip. On some types of soil, the tip of practically every leaf on all of the plants will be either white or dead and it is generally believed that continuous use of land for rice increases the prevalence of this disorder.

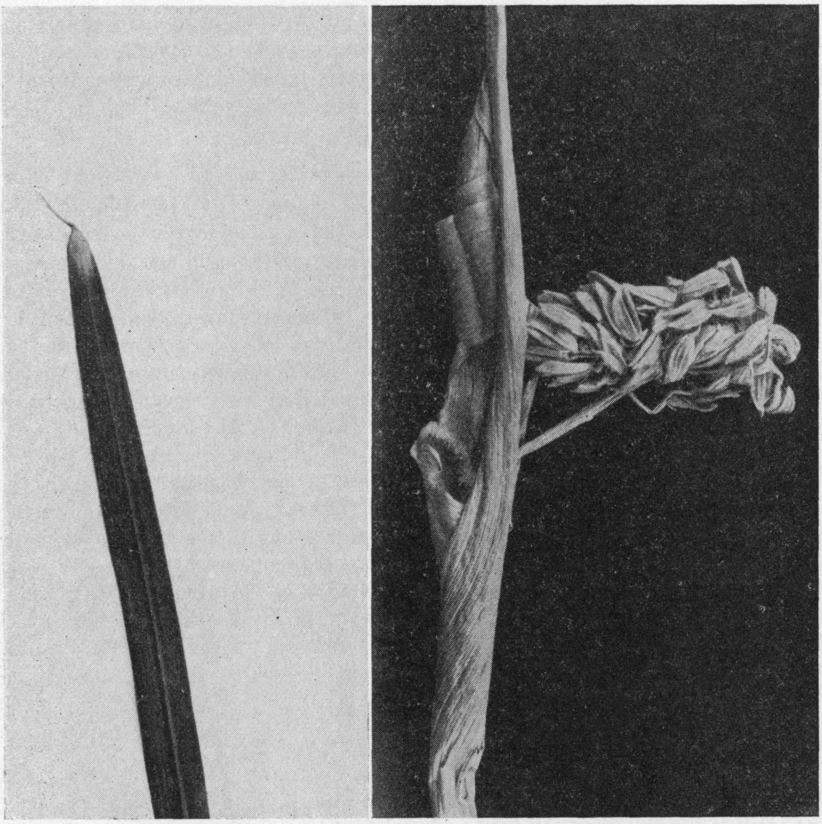

Fig. 2. White tip symptoms on rice: Left, leaf with dead, colorless tissues at tip; right, head injured by tightly rolled sheath.

The Effects of Magnesium and Calcium on White Tip

The white tip of rice is so similar to a condition reported in oats and wheat, claimed (1) to be due to a deficiency of magnesium in the soil, that a study was made of the effects of this element on rice. Since calcium is known to influence the action of magnesium as a fertilizer, the senior author has studied the effects of calcium alone as well as the effects of various quantities of both magnesium and calcium upon growing rice plants.

Soil which had previously produced plants with white-tipped leaves was selected from the Beaumont Rice Experiment Station plats. When Early Prolific rice was grown on this soil, white-tipped leaves appeared on 40 per cent of the plants. The first signs appeared after 10 weeks and from that time on various degrees of severity were observed. The addition of various quantities of magnesium to this soil caused white tip to become less frequent as the amount of magnesium was increased. When the minimum amount of magnesium necessary to eliminate white tip was tripled the plants died before maturity.

In order to evaluate the benefits which might occur if both magnesium and calcium were added to this soil, it was necessary to know what effect calcium alone would produce. When various quantities of calcium were tried on the soil, white tip was not affected and no other benefits were observed. The next step in this experiment was to add both magnesium and calcium to the soil. Both elements were added in all the concentrations previously tried thus giving a ratio of magnesium to calcium of 1:1 and in other cases the quantities of the two elements were varied so as to give ratios of 1:3, 1:9, 1:27, and 1:81. It was observed that a proper balance between magnesium and calcium was very important in order to avoid the white-tip condition. Although the addition of magnesium tended to eliminate white tip it was found to be toxic if applied in too high concentrations. The presence of calcium did not keep the magnesium from producing the desired effect yet it tended to permit higher concentrations of magnesium without injury to the plants. Benefits were produced over a much wider range of concentrations when both magnesium and calcium were added than when magnesium was added alone. The best results were obtained with this soil when similar quantities of magnesium and calcium were added. A more complete treatise on the effects of calcium and magnesium on white tip has been published elsewhere (4).

Recommendations for Controlling White Tip

The variation in nutrient properties of different soil areas must be considered when determining any corrective treatments. Trials conducted on a small scale should help to ascertain the requirements of similar larger areas. It is suggested, where white tip occurs, that 200 to 300 pounds of magnesium sulphate or 500 pounds of a high magnesium lime be applied per acre.

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