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# RED RICE

## Research and Control

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CONTRIBUTORS

**RED RICE: RESEARCH AND CONTROL**

Proceedings of a Symposium Held at

Texas A&M University Agricultural  
Research and Extension Center  
at Beaumont

December 13, 1978

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PREFACE

Red rice is one of the most common and troublesome weeds of rice in the southern United States. Estimates of losses caused by this weed have included 5 to 10 million dollars annually in Texas and 50 million dollars annually in the U.S. rice crop. These losses are due primarily to a reduction in quality and price caused by the presence of red grains in the white commercial rice and do not reflect the additional loss due to competition and reduced yield.

A red rice symposium was held at the Texas A&M University Agricultural Research and Extension Center at Beaumont on December 13, 1978, to bring together the latest information available concerning red rice and its control. Symposium speakers included a seedsman, rice producer, and research and extension personnel in weed control from Arkansas, Louisiana, and Texas. Over 175 interested producers and agricultural business representatives, primarily from Texas, participated in the symposium.

This publication makes the information presented available to a much wider audience than could be accommodated at the symposium. The speakers have revised their presentations into a form suitable for reproduction. I want to thank the speakers and their organizations for their efforts in creating a permanent record of the most up-to-date information available on a subject of major concern to rice producers.

E. F. Eastin, editor  
The Texas Agricultural Experiment Station  
Beaumont

## INTRODUCTION

J. P. Craigmiles

The purpose of this red rice symposium is straightforward and simple - to discuss the latest findings and procedures for controlling red rice. In accomplishing this we want two-way communication so that all present will become current on this most noxious weed of rice and its control. My brief remarks are intended as a definition of this problem.

Red rice can be defined as kernels which are distinctly red because of a red pericarp or outside bran layer. For purposes in this meeting, all types of red rice - strawhull red, bull red, vermilion red, long grain red and other kinds are included. Botanically red rice is generally classified as the same species as cultivated white rice, *Oryza sativa* L. Red rice crosses readily with white rice and is very similar to it in appearance. The main morphological differences that distinguish it from white rice are:

1. Seed have a red pericarp.
2. Seed shatter readily.
3. Seed remain dormant but viable in the soil for a long period of time.
4. Plants are generally taller and later in maturity than our current short season cultivars.
5. Plants and seed are usually pubescent.
6. Plants are lighter green in color.

All of these characters are genetically dominant over their alleles in white rice. Since these characters can be transferred by crossing, new red rice types can and do appear.

Red rice is undesirable because:

1. Red rice plants compete with cultivated rice reducing white rice yield.
2. Total yield is also reduced due to seed shattering of the red rice prior to harvesting.
3. Red rice seed lower the grade and price of the white rice sample.
4. Severe milling is required in samples containing red rice, reducing head rice and total milling yield.

Literature on red rice in the United States is rather limited. Published reports (1,2,3) indicate that red rice was present in fields of cultivated rice in the Carolinas as early as 1846. U.S. Department of Agriculture scientists listed four different red rice types in 1850. In all probability red rice was

shipped into the United States as a mixture in seed rice at an early date by the East Indian Seed Company. Red rice was definitely present in the rice fields of the American colonists long before rice cultivation began on a commercial scale in Texas, Louisiana, and Arkansas.

Worldwide literature makes mention of red rice centuries ago. Reports, particularly from India, describe red rice as a wild type growing along field borders and canals. Several comprehensive studies on the origin and taxonomy of rice classify red and white rice as the same species. Scientists are in general agreement that red rice originated from the complex group of wild rice *O. sativa* L. var. *fatua* Prain and has been modified greatly since its introduction by natural hybridization with cultivated rice (1).

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## RED RICE PROBLEMS - A SEEDSMAN'S VIEWPOINT

Clodis H. Cox

If it were not for red rice, I would not be here. I saw my first red rice while working on a farm on a 3-day pass when I was in the service. I saw a black hull down in the drill box, and I assumed that it would be just like one black sheep in a herd; when you got ready to shear them or eat them you would just pick the black one out and that was all there was to it. But it is not that simple. As I reflect back over those 35 years, I cannot help but remember what Mark Twain had to say: "It is not the things we think we know that get us into trouble, but the things we know we know that keep us in trouble." I think it has been the things we know about rice farming that has kept us in trouble.

I think our problem with red rice is not ducks and geese moving it from one field to another. The reason we have it is that we plant it and cultivate it. One of the reasons we have the red rice problem that we do in Texas today is probably because we waited so long before we initiated a seed program. Rice has been grown in Texas nearly 100 years. Our seed certification programs were set up based on problems that we were having 30 years ago. We as seedsmen need to recommend some more changes. The minimum standard for certified seed in Texas is two red rice seed in 10 pounds (lbs). If your seedsman sells you certified seed with two reds/10 lbs and you plant 100 acres, it will not take you very long to figure out how many grains of red rice you are actually planting. And if I understand the characteristics of red rice, if you let it mature in the field, in the harvest operation you will leave half of the seed in the soil. You then have a good start. I was visiting with a seedsman in Arkansas recently who came in with a handful of red rice that he had pulled out of his field. I asked him why didn't he cut the heads off in the field, and he said he didn't know that you were supposed to. He had shattered three-fourths of the grain back in the field. Another reason for the red rice problem is our technology. Although herbicides have increased our production, and relieved rice plants of competition from other weeds, they have allowed red rice to increase.

We have problems with red rice that were created years ago. I believe that we will never be completely free of red rice. If we use good cultural practices, such as soybean rotation programs where we use herbicides and do a little roguing in our soybean fields, there is no reason why we should not be

able to control it. Basically, we must do three things to overcome red rice. First, it is going to require hard work. We are going to have to rogue it, and I mean by roging not just pulling it out of the ground. If you spot a rice plant in the field, look in all directions because there is always more than one. Ease up to it very gently, pull the head over in a bag and clip it off, and then pull the root up and put it in the bag. That is the only way to get rid of it. The second thing we must do is spend some money. If we all made 35 barrels of rice to the acre this year and got \$20.00 a hundredweight (cwt) for it, I dare say there would not be very many people here today. But we are in a bind. One of the things a farmer thinks he can do to overcome his problems economically is to spend less money for seed. When farmers begin demanding good seed, that is, red-free seed, we will produce it, but it will cost money. The third thing that we can do is encourage the people here at the Station. They have a good program and good people. They have gotten us out of many problems before, and they will help us again if we give them our cooperation and support.

## RED RICE PROBLEMS - A PRODUCER'S VIEWPOINT

W. D. "Bill" Dishman

With the increased cost of production, each farmer must have an economically sound program for control of red rice. Infestation levels caused by improper management practices in Jefferson County, Texas, have reached alarming percentages in our rice lands. Each farmer must evaluate the needs of his fields and plan to effectively reduce red rice levels.

Red rice comes primarily from these sources: planting impure seed rice, shattering losses during harvest, and turning under mature seed in fall preparation of fallow or cropped land. Control of red rice is part of management and one must be willing to make decisions and implement control practices.

The following is an illustration of a planned program to eliminate red rice. In 1976 a 223-acre field was abandoned for rice production because of red rice infestation. During the winter the field was water leveled, then cultivated and land leveled in the spring. Lasso (see Appendix for chemical identity) at the rate of 4 quarts per acre was applied, non-incorporated, and the field was flushed with irrigation water immediately. The field was then broadcast planted to Bossier soybeans at the rate of 50 lbs/acre.

Results were about 95 percent control of red rice and a crop of seed beans of good quality, which were harvested on dry ground. After harvest the levees were pushed (the ground was not cultivated); then winter rainwater was collected to cover the small amount of red rice that shattered and fell to the ground. The field was drained in February with a total decomposition of the surface red rice seeds.

In 1978, the field, planted to rice, produced excellent yields. In addition, rice quality improved, on the average, from loan values of approximately \$6.90/cwt the previous year to \$7.45/cwt. The program was evaluated as effective and economically sound.

## CULTURAL CONTROL OF RED RICE

E. A. Sonnier

Judging from the attendance at this symposium, I can see that there is very definite concern about the red rice problem. Many of you have dealt with this noxious weed and have been frustrated, as I have, at the fact that it simply will not go away. I would like to believe, however, that in this group we also have some people who are not really familiar with red rice, but want to learn about it in case they are confronted with it in the future.

If you talk to rice farmers from different areas, you hear terms like vermilion red, guinea red, gumbo red, and even bull red. It is true that variations in red rice can be found in different localities, and that red rice will hybridize with our domestic rice varieties to take on new forms. If one of these red grains gets to the Plant Board office in Austin, you can bet that it will be called red rice whether it is pure or not. In spite of all the variation and hybrid forms which occur in red rice, you will find that all of them fall into two main groups or types: strawhull red and blackhull red, based on hull color.

Strawhull red rice has a somewhat open plant with relatively few tillers. It has drooping panicles and leaves which are rough, pale green, and a bit narrower than those of our domestic varieties. It may or may not have whiskers or awns. The growing period of strawhull red is about 120 to 130 days.

Blackhull red rice is a more dense, compact plant. It is not unusual to find as many as fifty or seventy-five tillers. The leaves are narrow, pale green, rough, and very erect. Frequently the panicles fail to come completely out of the boot. The seed almost invariably have awns. Blackhull red matures a bit later than strawhull. In date-of-seeding experiments it was found to mature at about the same time as Bluebonnet 50.

Differences also exist between blackhull and strawhull red in the shading of the bran layer of the dehulled kernels, and in the size, shape and translucency of the milled kernels. The strawhull kernels tend to be more blocky and have a big chalky spot which is absent in blackhull red.

What both types have in common is that they are weeds, wild plants, which are able to withstand adverse weather conditions. In addition, the seed have great longevity in the soil; and, finally, the red rice seed end up either in the domestic rice sample, lowering its quality, or in the soil, reducing yield and perpetuating the infestation.

### Cultural Practices to Combat Red Rice

There are a number of cultural practices which can be used to combat red rice. A word of caution at this time - in our experiments we are working with infestations of more than 250 red rice seed per square foot, rates which are not at all uncommon in heavily infested fields.

#### Water Management

The first cultural practice I would like to discuss is water management in conjunction with water seeding. I stress water seeding, because if rice is drill-seeded or broadcast on a dry seedbed, the farmer is not availing himself of one of the major advantages of the water management practice, namely suppression of red rice with floodwater.

After water seeding the farmer has three options for handling floodwater. Option 1 is to maintain a continuous flood from planting until pre-harvest drainage. Option 2 is to drain the water shortly after seeding and re-flood the field gradually as soon as the domestic rice seedlings take root. Option 3 is the traditional practice in which water is drained after planting and re-flooding delayed until the domestic rice is large enough to withstand a full flood. Some growers find it necessary to flush the field at least once during this time, and some even apply a herbicide during the period of drainage.

Now, some comments about these three practices. Option 3, involving prolonged drainage, is very common. It works well in establishing a stand, but insofar as red rice control is concerned it is no better than drilling the rice or broadcasting and harrowing. Option 1, continuous flooding, is not widely accepted in Louisiana. Some farmers have used it to good advantage; however, certain risks are involved. In soils containing much humus, it may be impossible to establish a stand in the resulting murky water. In other cases, wind may cause wave action which can uproot young seedlings and send them against the levees, further reducing the stand.

Option 2, or pinpoint flooding as it is sometimes called, is a compromise. Keeping the soil moist by re-flooding early helps to suppress germination of much of the red rice. The domestic rice seedlings, on the other hand, take root more quickly and resist uprooting and drifting. The seedlings tend to be less spindly than those which result from continuous flooding.

Prolonged drainage does nothing to control red rice. Continuous flooding, however, gives good control; and pinpoint flooding gives intermediate control. The few red rice plants which occur in continuously flooded plots produce a great

number of tillers and consequently a great amount of seed. Prolonged drainage, on the other hand, results in many small red rice plants, each of which produces relatively few seeds.

How do the different water management treatments affect the yield of domestic rice? In experiments at Crowley, under continuous flood, only 3.3 percent of the total yield was red rice, while prolonged drainage resulted in a greatly reduced yield consisting of over 40 percent red rice. I have spoken with farmers who took pride in the fact that they had a bad red rice problem and yet harvested No. 1 and No. 2 rice, never stopping to think what that large population of red rice seed would do to them next year after dropping to the ground.

Anyone interested in trying one of these practices should set aside a small cut in an infested field to prove to himself what continuous flooding or pinpoint flooding can do and whether it is worth the risks involved.

#### Rotation of Rice with Pasture

Before soybeans became popular in Louisiana, the prevailing rotation involved rice and either improved or unimproved pasture. It is not uncommon to find red rice plants volunteering in pastures. For that reason, farmers feel that in addition to grazing, mowing or clipping red rice will increase the degree of control, by preventing it from heading and setting seed.

Let's consider pasture-grown red rice. In a wet season, as we sometimes experience in Louisiana, red rice plants may be 20 to 22 inches tall and fairly productive. In a dry season, or where it is grazed heavily, it may be a short stubby plant, and require a month longer to mature than it would if it grew in a wet rice field, but it will produce seed. In either case, wet season or dry, pasture-grown red rice will produce seed unless it is controlled.

We conducted an experiment at Crowley in which red rice was mown to 2, 3, and 4-inch heights before heading and at weekly intervals thereafter for from 14 to 42 days. Before each mowing, we collected and stored any seed which had been produced for subsequent germination tests.

Red rice, clipped to 2 inches, regrew to a height of 12 inches in 21 days and panicles had already begun emerging from the boot. Red rice which was clipped to 4 inches had reached a height of about 14 inches in 21 days and the seed were more mature than those on plants that had been mown to 2 inches. And finally, red rice which was mown to 4 inches was allowed to grow for 28 days. It was almost 20 inches tall prior to mowing, very leafy, and had several panicles. In a few more days its seed would have been sufficiently mature to shatter.

During this experiment, we learned that a uniform infestation of pasture-grown red rice of eight plants per square foot, if not clipped, can produce between 1,500 and 1,800 viable seed. The germination of seed collected from the control plots usually averaged about 90 percent. We also learned that, in order to prevent the production of any live seed, it was necessary to mow very frequently or to "SKIN" the pasture, that is, to clip the red rice very short. However, the farmer would find either of these methods impractical. From a practical standpoint, it was found that mowing the pasture twice during the season at 42-day intervals to a height of 3 inches would reduce the infestation from 1,800 pounds to 6.5 pounds per acre. Two mowings to 3 inches spaced at 28 day intervals further reduced the infestation to 1.2 pounds of live seed per acre. Our experiment clearly demonstrated that in no instance would a single mowing prevent the production of viable seeds - at least two mowings are necessary for reasonably good red rice control.

#### Fallow Plowing

One of the most effective methods of controlling red rice is fallow plowing. Mr. J. Mitchell Jenkins referred to this practice in reports of the Louisiana Rice Experiment Station before 1920. Fallow plowing is nothing more than working the land several times during idle seasons in order to destroy several successive crops of red rice before they can produce seeds. The two objections that are most often raised against fallow plowing are: 1) "No matter how many times I plow, the same amount of red rice keeps coming up--I can't seem to kill all of it." 2) "I cannot fallow plow, because it interferes with alternate cropping of my land. I cannot grow beans or graze my land and fallow plow it at the same time."

Let us consider the farmer's first objection. Data were collected from a small, heavily infested area at the Crowley Rice Station where we conduct red rice work. Prior to the first plowing in early May, we counted about 15 red rice plants per square foot. Prior to the second plowing which was done a few weeks later, we found 30 to 32 plants per square foot. As we continued plowing throughout the summer, however, the amount of red rice gradually declined. However, in the spring of the following year, there was again a fairly heavy infestation, but it declined very rapidly with repeated plowings during the second summer. The problem here is that dormancy in red rice causes it to behave differently from the domestic varieties. To rid the land of volunteer rice of domestic varieties, it is necessary to plow once in the fall and possibly once the following spring. Another commercial variety can then be planted with little concern about mixtures.

But to reduce red rice significantly, a 2-year fallow plowing program must be conducted.

In answer to the second objection, I would like to point out a number of alternatives to continuous plowing. We realize that in an alternate cropping system you cannot plow as frequently as we did in this study. But after harvesting a rice crop you can destroy the stubble to prevent red rice from producing a second crop and further increasing the problem. Grazing the stubble is usually not sufficient to prevent the production of additional red rice. The next alternative would be to destroy two crops of red rice during the following spring prior to planting soybeans. This can be accomplished even if you plant beans as early as May 1.

We have observed, if the weather warms up during February, rice seedlings often sprout in fields that were harvested the previous year. A careful check will indicate that these are seedlings of the domestic variety and not red rice. If you will check the field about April 1, you'll see the red rice seedlings. You can verify this by splitting open the hulls or glumes so that the red seed coat is visible.

Two fallow plowings in the spring, the first in early April and the next in early May, will destroy two additional crops of red rice. Then, additional red rice can be destroyed by using a chemical herbicide program in the soybean crop. If any red rice survives the chemical control, there may still be an opportunity to control it by cultivation or possibly by roguing. Any remaining red rice stubble can be chopped up after the beans are harvested. In this regard I do not wish to contradict Mr. Dishman. I agree with him that if you're dealing with mature red rice you want to avoid plowing it under, in effect, planting it. But any plants which have not headed should be destroyed, and in so doing you can encourage another crop to sprout - even as late as October 15. As you can see, then, rice and alternate crops present plenty of opportunities for combating red rice.

#### Stubble Burning

I would like to call attention to another practice which was once very prevalent around Crowley. Farmers sometimes set fire to their fields to burn the stubble and thereby destroy shattered red rice seeds. I do not have much respect for that practice because, in the first place, it destroys valuable organic matter. Secondly, you will find that unless the straw is fairly thick (as it is directly in the path of the combine) the fire is not sufficiently



intense to destroy the seeds. It is possible to collect seeds from those fields which are completely untouched by the fire, and others which have been partially burned on the end opposite the embryo. They will sprout quite well in a germinator. In fact, it may be that the heat helps to overcome dormancy.

In sampling a recently harvested soybean field, we found areas in which there were as many as 1,100 red rice seeds per square foot of soil surface. Situations such as these prompted an individual in South Louisiana to build a device that was designed to concentrate an intense flame on the soil surface in order to completely incinerate the red rice seeds. It was tested in a heavily infested field at ground speeds of 2 and 4 miles per hour. At the higher ground speed, it was found that the seeds were not exposed to the flame long enough for complete incineration as almost half the seeds survived. At 2 miles per hour about 75 percent of the seeds were killed, but the fire endangered the tires and hoses of the burning device. In addition, the fuel consumption and cost per acre of operating the burner made it impractical. However, this is an example of what producers will try to rid themselves of red rice.

### Roguing

A cultural practice which I have not mentioned until now is roguing, the practice of removing red rice and other noxious weeds by hand from the growing crop. The pros and cons of roguing can be summed up as follows: If done properly, the cost of roguing is very high. In most situations, especially in broadcast rice, roguing can be very destructive as many domestic rice plants are knocked down and trampled. And finally, if a light infestation of red is found in a field of seed rice, the farmer may find it necessary to risk the destruction of some white rice. In other words, he can't afford not to rogue.

In conclusion, you have to stand in one place and look around. And when you see that tall plant out there, you can bet that two or three more are somewhere around it, hiding in the rice. You have to get them all. Otherwise, you'll find yourself in the shoes of the man who complains to us "I used to make seed rice on this field. Now I'm making 2's and 3's." Believe me, the red rice situation does not remain static. It either improves or it gets worse, and I'm hoping that with the information presented at this symposium, that we can all work together to put red rice on the endangered species list.

## RED RICE CONTROL IN ALTERNATE CROPS

Ford L. Baldwin

The topic that I would like to cover with you is red rice control in alternate crops. All of the material I will be covering is based on research conducted by Dr. R. J. Smith, Jr., USDA-SEA-AR, for whom I am substituting today. I will be talking primarily about soybeans and grain sorghum. Research at Stuttgart, Arkansas, has shown that three red rice panicles per square foot can reduce rice yields 64 percent. Probably some of you have had experience with it getting even worse than this. We have seen fields left unharvested because of red rice.

I am going to begin with a crop rotation study by Dr. Smith. Let's set the stage by looking at the rotation study as a whole and the effect that it had on the rice crop. Then let's consider some of the individual treatments that go into each one of these rotation crops and, finally, talk a little bit about specific controls. About 1969 our rice research and extension personnel could see the red rice situation getting worse and made the decision that the research effort was going to have to be expanded. Dr. Smith chose a field in South Arkansas on which the red rice problem was so severe that rice could not be grown commercially anymore. He wanted to test a number of rotation programs to see if they could put the field back into rice production. We have always felt that a one-in-one-out rotation would not control a bad infestation of red rice, so almost everything I will cover is a two-out-one-in rotation (2 years out of rice).

The rotation used was either soybeans, soybeans, rice; soybeans, grain sorghum, rice; or grain sorghum, soybeans, rice. A check treatment of continuous rice was included. The year the experiments were begun, 99 percent red rice control was achieved in soybeans. Keep in mind we were not just planting soybeans, we were doing everything that we could possibly do to control red rice in the alternate crop. I will get into those details a little later. Soybeans gave 99 percent control of red rice the first year and 92 percent control the second year. A return to rice gave only 26 percent control of red rice the third year. After going through the cycle again with soybeans, soybeans, then rice, 79 percent control of red rice was achieved in the second rice cycle. Grain sorghum in the grain sorghum, soybean, rice rotation gave faster control of red rice, regardless of when it went into the system. During the first year back into rice 73 percent control was obtained and then two times back through the cycle up to 90 percent red rice control was achieved in the rice crop itself.

What about the rice yields? Continuous rice yielded 700 pounds per acre the third year (rice in the first rotation cycle). No rice was harvested in the second rotation cycle because the red rice lodged the white rice in the bloom stage so that the combine was not put in the field. That was the type of pressure that we were working under. In the soybean, soybean, rice rotation, the first year back in rice, yield was 2,000 pounds per acre, and the second time through the cycle at the end of 6 years yield was back up to 4,500 pounds per acre. Basically, the end results were the same whether they were in soybean, soybean, rice or soybean, grain sorghum, rice rotations. The second time through the rotation, in a field which had been producing nothing in continuous rice, yield was back up to 4,500 pounds per acre of No. 2 rice, and head rice yield was back up where it ought to be.

Now what were we doing in the alternate crops through the rotation system? I am going to cover grain sorghum first because it will not take you long to see that we do not have any problem controlling red rice in grain sorghum. The problem is that grain sorghum has not developed as a crop in Arkansas in the area where we need to be rotating it with rice, which is unfortunate from a red rice standpoint. One of the treatments that Dr. Smith has found successful is propazine preplant incorporated (PPI). Propazine averaged 100 percent red rice control over 3 years. Propazine PPI and atrazine over the top of 4- to 6-inch sorghum were added to our recommendations for red rice control based on his results. In 1978, newer treatments that resulted in 90 percent control or better included Dual with a sorghum seed protectant and Paraquat CL postemergence directed.

Now let's switch to soybeans. The normal rotation program with rice is soybeans in Arkansas; so, that is the crop in which we want to control red rice. We recommend that the preemergence herbicides be applied PPI since they give more consistent control PPI than preemergence. For instance, Lasso preemergence may give 99 percent control of red rice if we have timely rains, but only 50 percent or less if it is dry; incorporation takes out much of the dependence on rainfall for herbicide activity. In Dr. Smith's research, Lasso at the maximum label rate of 3.5 pounds per acre and double rates of the dinitroaniline herbicides, such as Treflan, Tolban, Basalin, Prowl, etc., have given good red rice control. Addition of metribuzin (Sencor or Lexone) does not increase red rice control but improves broadleaf weed control.

Our recommendations include follow-up postemergence directed treatments of Paraquat CL when the soybeans are 8 inches tall with another treatment 1 week later to control the red rice that the PPI treatment misses. The reason for the

use of postemergence directed sprays is that we have not come up with the herbicides that can go over the top of soybeans to control red rice that escapes the PPI treatments. In the last 3 years, rice producers in the big rice farming area of Arkansas have gone to the directed sprays, whereas before they would not consider them. They put it off a long time, but when you go out there and raise those soybeans up and see the dead red rice and you see the dead morningglory, it makes it worthwhile. There are many different rigs you can use, since all you are doing is directing the spray underneath the soybean. The spray rigs are not really that hard to operate, and have put consistency in the red rice control program in soybeans. Just wait until the bean gets 8 inches tall and spray underneath it with Paraquat CL. It is not expensive - a gallon covers 32 plus acres, so you are talking about less than a dollar an acre per application. Even if you do it twice you have less than \$2.00 in chemical cost for the directed spray, and it is death on red rice if you time it right.

In over-the-top treatments, about the only thing that has looked encouraging in Dr. Smith's research has been a 3M compound called Vistar. A half-rate of Vistar and a half-rate of Basagran over the top of small soybeans and red rice has basically given complete control in 2 years of research. If Vistar gets labeled, perhaps you will have an over-the-top option for soybeans. But what will happen if it is too expensive to broadcast? You will have to go back to a band treatment with a ground rig. Many times when you do that you may as well be post-directing. I am not trying to discourage you from using Vistar, I am just saying do not put off going to a post-directed program if that is the way you need to go. Don't wait on something new because it may not be marketed until 1980 or 1981, and you have got to farm next year, too. Hopefully, we will have something that will help us out down the road.

Normally we think about red rice control in soybeans for the rice crop. However, severe infestations of red rice have reduced yields by 3 bushels per acre in research and that will more than pay for the extra cost of herbicides used in the soybeans.

To summarize, the technology is there. You are going to have to combine it with a lot of other things, but if you will take the best technology we have available in a rotation program, you can make a big dent in your red rice problem.

## RED RICE CONTROL<sup>1/</sup>

Bobby A. Huey  
and  
Ford L. Baldwin

Red rice is costing Arkansas rice farmers an estimated \$10 to \$12 million annually. Discounts can range from \$.05 to \$.75 per bushel in addition to yield loss. How much is your share?

Recently, control programs have been developed to reduce red rice on infested land. These systems integrate preventive, cultural, mechanical, and chemical practices. The best approach for an effective control program is the use of crop rotation, herbicides, and cultivation practices. Such systems can be implemented with proper management inputs.

### What is Red Rice?

Red rice is an inferior rice of the same species as white rice and is considered a weed in crops produced in Arkansas. Red rice has a red seed coat instead of the normal brown one of commercial rice.

The major types of red rice in Arkansas are straw-hulled and bearded black-hulled medium grain varieties. Straw-hulled is by far the most predominant and matures in about the same length of time as Nato. The black-hulled type has Starbonnet maturity. Straw-hulled has slightly larger kernels than black-hulled rice and thus is difficult to remove from white rice during milling.

Red rice seed can remain viable in the soil for many years. However, most of it is depleted after two years if the land is cultivated and no more red rice seed is produced during those years. Plants tiller (stool) profusely. It competes with rice for nutrients and sunlight. Heavy infestations cause shading and lodging of white rice because red rice plants have tall, weak straw. Red rice plants are not easily distinguished from the white variety until heading occurs. However, the leaves of red rice have short, stiff hairs on the upper and lower surfaces which feel rough and distinguish red rice leaves from commercial varieties which have smooth leaves.

Red rice plants are usually taller and may be lighter green than regular rice. The black-hulled type has shorter, narrower, more erect leaves, more

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<sup>1/</sup> Reprinted from Arkansas Agricultural Extension Service EL 604. Dr. Roy J. Smith, Jr., research agronomist, USDA-SEA-AR, Rice Branch Experiment Station, Stuttgart, Arkansas, contributed data and assistance in the preparation of this publication.

tillers, fewer grains per head, and more open panicles than the straw-hulled type. Red rice grain shatters easily and often before the rice crop matures. The seeds have "fuzz" or are hairy in contrast to the smooth hulls of commercial varieties. A few red rice seed are viable 10 days after flowering; however, at 23 days after flowering viability is excellent.

There are no red rice parents in recent commercial U.S. rice varieties. There is little likelihood of "throwback" or seed "running out." Although rice is 99.9 percent self-pollinated, natural crossing is possible. When this occurs, all of the first hybrid generation and 3/4 of the second generation have red bran; thus, red rice propagates at a fast rate. Red-white crosses may have the same plant characteristics as white rice and are impossible to locate and rogue from fields.

Red rice is just as nutritious as white rice, but consumers prefer white grains.

#### Why is Red Rice Unwanted?

Rice millers don't want red rice because:

- Mixtures with white rice must be overmilled to remove the red bran which lowers head rice yields.
- Red rice breaks easily in milling and is chalky.
- Markets that will give good prices are limited.

Seed producers and dealers don't want red rice because:

- Their reputation for supplying pure seed may be ruined.
- They can sell rice free of red rice at a higher price and usually make more profit.
- The cost of producing seed free of red rice is inflated.

Rice producers don't want red rice because:

- A few plants represent a potential problem.
- Red rice decreases yield and quality reducing profits.
- Control is difficult and expensive.
- Different cropping systems may be required.
- Red rice affects variety selection, planting dates, and weeding methods.
- Red rice causes shading and lodging which increase harvesting costs.
- Low grades of rice are difficult to sell during years of plenty.
- Rice with red rice may be discounted.
- Red rice limits seed sales.
- Red rice may become a weed in the alternate crops and force changes in irrigation and weed control.

Red rice is spread primarily by planting seed that contains red rice. Since it scatters easily, it may accumulate in the soil for several years before red rice grains are noticed in harvested grain. Red rice may be accidentally transferred from field to field by combines, grain carts, and trucks. Also, contaminated soil may be moved from infested to clean fields by land preparation, equipment, or even with mud on workers' boots. Birds, including ducks, digest red rice seed and do not transfer red rice from infested to clean fields.

Red rice has been increasing in Arkansas for several reasons:

- Urgency of securing seed of new and promising varieties of questionable purity including Labelle, Lebonnet, and Brazos during the time of increasing acreage in 1974-1976.
- Delayed rice planting because of the wet spring of 1974 required farmers to change to very short-season varieties that were in critically short supply. To get the planting seed, farmers purchased milling quality rice that contained more red rice than certified seed. Even milling quality rice "cleaned" to remove the red still contained red rice grains.
- Continued use of locally available seed of questionable purity.
- Expansion of rice acreage and/or expanded fish production reduced the time land was planted to alternate crops. Some farmers grew rice continuously for several years.
- Inadequate use of control systems. Frequently, only one method, such as preplant treatments of Lasso or Treflan without additional practices to control escapes, were used.
- Increased irrigation of soybeans, which often enhanced production of red rice seed.

### Red Rice Control

#### Prevention:

The first step in controlling red rice is to prevent infestations. This can be done by planting seed free of red rice. The following table shows the purity standards of the Arkansas certified seed program.

Rice Standards for Seed Certification  
Red Rice Factor<sup>1/</sup>

	Foundation	Registered	Certified Blue Tag
Field Inspection	None	None	1 plant/A
Cleaned Seed	None	None	1 per 2 lb <sup>2/</sup>

<sup>1/</sup> Excerpt from circular 12, "Official Standards for Seed Certified in Arkansas," by the Arkansas State Plant Board.

<sup>2/</sup> Two lbs. to be hulled per 400 bags or less in each lot.

Pure seed is especially important when bringing new land into rice production.

Prevent the removal of soil from infested to clean fields from land preparation, equipment, and mud from tires. Also, harvesting equipment, including combines, grain carts, and trucks should be thoroughly cleaned after handling grain in a red rice infested field.

Cultural Practices:

Keeping rice fields wet and rolling straw after harvest enhance germination of red rice that will be killed by frost before seed is mature. This may also encourage ducks, which consume a large portion of red rice, to inhabit the field.

Row crops which allow cultivation will effectively control most red rice plants except those in the drill. Delaying planting dates will allow much more time for germination and destruction of red rice with land preparation equipment. Early spring cultivation and smoothing the soil with a harrow or similar implement will stimulate germination and may allow a producer to destroy several flushes of red rice before planting crops such as soybeans. Land leveling and filling potholes eliminates perennial sources of red rice seed.

Rotation:

Red rice grows best in an aquatic habitat. Therefore, planting infested fields in crops other than rice can reduce red rice seed production. Soybeans, grain sorghum, or cotton seeded more than two years, utilizing effective control measures, will usually reduce red rice infestation to a manageable level.

1. In a 6-year experiment, during 1970-76, on the John Schenk farm near Monticello, red rice was reduced by combining chemical and cultural practices in a soybean, soybean, rice or a soybean, grain sorghum, rice rotation. Two cycles through the rotation covering a 6-year period each improved production from 700 lb/A of sample grade rice at the beginning to 4,500 lbs/A of No. 2 rice at the end of the experiment.



2. In a 6-year experiment initiated in 1973 at Stuttgart, excellent yields and quality of rice were produced after only two years of soybeans or grain sorghum treated with newer and more effective herbicides than those available during the Monticello study.

The best herbicide treatments to control red rice in soybeans are:

1. Lasso @ 3.5 qt/A applied preplant and incorporated 2 to 3 inches during final seedbed preparation.
2. Paraquat @ 0.5 pt/A (broadcast rate) mixed with non-ionic surfactant and post-directed to soybeans 8 inches or taller to kill red rice plants in the drill that escape preplant herbicide treatments. If broadleaf weeds are present, add 2,4-DB at 1 pt/A (broadcast rate).

Effective alternatives are Treflan at a 2X rate for the soil type applied preplant incorporated. Tank mixes of Lasso, Tolban, Prowl, or Treflan plus Sencor or Lexone at recommended rates give fair to good control of red rice. All treatments must be followed by the Paraquat previously mentioned.

Before irrigating soybeans, every effort should be made to rid fields of red rice by post-directed sprays and cultivation. Otherwise, irrigation enhances red rice growth and seed production and will defeat previous control efforts. Red rice that emerges in potholes or other localized areas late in the season should be disked to prevent it from producing seed. Sacrificing small acreages of soybeans may be a small price to pay to keep from losing the benefit gained by the rotation system.

#### Grain Sorghum:

The best herbicide treatment for red rice in grain sorghum is Milogard preplant incorporated at 3 to 4 lbs/A of 80 W or 2.4 to 3.2 qts/A of 4L. Residual activity lasts six to eight weeks. Late reinfestations may occur, but plants usually are immature when the grain sorghum is harvested. Destroying stalks soon after harvest prevents red rice from producing seed. In five years (1973-1977) of experiments at Stuttgart, Milogard incorporated preplant controlled 99 to 100 percent of the red rice in grain sorghum. In two years' research, atrazine early post has given 100 percent control of red rice.

#### Rice:

If rice must be seeded in fields infested with red rice, Ordram (8E) at 4 pts/A or Ordram 10G at 40 lbs/A can be incorporated about 2 inches deep by double disking during the final seedbed preparation. This treatment combined with water management gives partial control of red rice and excellent control of barnyard-

grass. After herbicide treatment, the crop is waterseeded and the floodwater is held continuously. If the field must be drained to obtain a rice stand or to expose weeds to herbicides, keep the soil saturated by timely flushing to inhibit red rice germination. Don't let the soil dry and crack. Control with water is based on the fact that red rice does not germinate when covered by soil and water but will germinate when covered by either one alone. The use of Ordram, water-seeding, and water management usually control 80 to 90 percent of the red rice plants. It is best to combine control in the rice crop with control practices in the alternate crops.

See chart below on red rice control at Pine Tree and Stuttgart.

Control of Red Rice in Water-Seeded  
Rice with Ordram and Water Management,  
Pine Tree (1973-74) and Stuttgart (1977)<sup>1/</sup>

Herbicide and Water Management <sup>2/</sup>	Pine Tree		Stuttgart
	1973	1974	1977
None, drained	0	0	0
Ordram, flooded	80	80	89

<sup>1/</sup> R. J. Smith, USDA-SEA-AR.

<sup>2/</sup> Ordram at 3 to 4 lbs/A incorporated preplant; continuous flood maintained for 4 weeks after seeding.

Check List for  
Red Rice Control

- ( ) Use red rice-free seed.
- ( ) Avoid contaminating red rice-free fields with equipment.
- ( ) Roll rice stubble in fall.
- ( ) Eliminate potholes in rice and soybean fields.
- ( ) Rotate from rice to other crops.
- ( ) Destroy volunteer red rice by disking and smoothing field several times before planting.
- ( ) Use ppi herbicides such as Lasso or 2X Treflan.
- ( ) Plant soybeans in rows.
- ( ) Use post-directed herbicides.
- ( ) Cultivate.
- ( ) Eliminate escaped spots in soybeans.
- ( ) Plow and smooth soybean fields after harvest.

In summary, each of the above items in the check list has a place and must be combined into a systems approach designed to use up the red rice seed supply in the soil. One red rice plant uncontrolled can theoretically produce 135 lbs/A of seed after two years (see table below).

#### Red Rice Population Explosion

Year	Population Per Acre	Population <sup>1/</sup>	
		Seed/A	Lb/A
1	1 plant	1,500	0.1
2	1,500 plants	2.25 M	135

<sup>1/</sup> Assumes 1 plant with 10 tillers with 150 seed per head and 100% germination for the second year.

## RED RICE HERBICIDE SCREENING TESTS

J. B. Baker  
and  
W. J. Bourgeois

During the last 5 years, we have screened 94 herbicides in a laboratory study in which we evaluated herbicide toxicity in two types of red rice, four commercial varieties, and one commercial variety treated with the "herbicide antidote" 1,8-naphthalic anhydride. Based on this test it is possible to determine if a herbicide is more toxic to red rice than to the commercial varieties and if the "antidote" provides protection against injury. Herbicides tested have included 14 thiocarbamates, 7 carbamates, 13 dinitroanilines, 9 acetanilides, 3 amides, 10 diphenylethers, 9 triazines, and 28 miscellaneous or confidential. Of these, 24 have been evaluated further in field tests. Some of these, along with new additions, will be tested further in future field studies.

At this time, none of these compounds has shown a higher degree of selective red rice control and crop tolerance than we have obtained with molinate in field studies. Detailed studies with new slow-release granular formulations of molinate have failed to show a significant increase in control over that obtained with the standard granular formulation. At a rate of 3 pounds of active ingredient per acre, applied preplant incorporated, red rice control ranged from 75 to 85 percent.

## BASIC RED RICE RESEARCH IN TEXAS

Charles W. Helpert and E. Ford Eastin

Very early in our work on red rice, we realized that the probability of finding a herbicide in a screening study which would selectively control red rice in cultivated rice was not very great. Several chemicals seem to give good to excellent control of this problem weed but the control was not consistent. Thus we have concentrated our effort on the growth characteristics of red rice, hoping to find a "weak link" in the life cycle that we can use to advantage in a control program.

Some of the first studies we conducted were depth of germination and emergence studies. The main objective of these studies was to determine from what soil depth both blackhull red rice and strawhull red rice were capable of germinating and emerging. This is important because certain herbicides are primarily root absorbed, some are absorbed mainly by the germinating seed, and some by the developing and emerging shoot. If the herbicide is absorbed by the emerging shoot, good control should be observed no matter from what soil depth the shoot is emerging. On the other hand, if the herbicide is mainly absorbed by the germinating seed or developing roots, the herbicide would have to be present in that area in concentrations high enough to provide control. For example, if a herbicide is soil incorporated to 2 inches and red rice emerges from 4 inches and the herbicide is only absorbed by the roots, very little control will be observed. On the other hand, alachlor (Lasso), which is absorbed by germinating seeds and shoots, provides good to excellent control of red rice in soybeans.

In growth chamber studies Price (1) soil incorporated molinate (Ordram) to 2.5 cm (1.0 inch) and got 90 to 95 percent control of red rice planted in the treated zone. Only 30 to 50 percent control was observed when red rice seed were planted 5.0 to 6.5 cm (2.0 to 2.5 inches) deep.

We conducted four depth-of-emergence studies. Two were conducted at Garwood, Texas, on Crowley fine sandy loam soil, and two were conducted at Beaumont in a greenhouse on Crowley fine sandy loam and Beaumont clay soils. Twenty-cm (7.9-inch) sections of 10 cm (4-inch) polyvinylchloride (PVC) pipe were driven into the soil and the soil inside the tubes was removed. Seeds of seven rice varieties - blackhull red rice, strawhull red rice, Dawn, Early Colusa, Labelle, Nato, and Starbonnet - were planted at 0-, 1-, 2-, 4-, 8-, 12-, and 16-cm depths inside the cylinders in both the field and greenhouse studies. Plant counts and plant height measurements were taken at 3, 10, 17, and 24 days after first emergence.

When averaged over all soil depths, blackhull red rice and strawhull red rice produced higher emergence percentages and taller plants 3 days after emergence than

the other five rice cultivars. The higher emergence percentages for red rice held true even after 24 days, although the plant height at 24 days was not different from Nato, Labelle, Dawn, and Early Colusa. Comparing soil depths, averaged over all varieties, more germination and emergence was observed from the 1-, 2-, and 4-cm soil depths than from the other depths.

Comparing blackhull red rice and strawhull red rice with Labelle, no emergence was seen for Labelle at 4-cm depths at 3 days, whereas both red rices germinated and emerged from 8 and 12 cm. After 10 days and 17 days, the emergence of Labelle was still behind both the red rices, although the differences were not as great as before. Emergence of strawhull red rice was observed from as deep as 16 cm.

Summarizing the depth-of-emergence studies, both types of red rice are apparently capable of germinating and emerging quicker and from greater soil depths than commercial rice cultivars. Any herbicide or cultural practice developed to control red rice must take these factors into account.

Another phase of our red rice research concerned the germination and dormancy of red rice. Our objectives were to determine 1) at what time after heading red rice seed would be viable, (2) the initial dormancy of blackhull red rice and strawhull red rice as compared to the rice cultivars discussed above, and (3) the length of dormancy of red rice compared to five rice cultivars when stored at a given temperature.

Rice panicles were tagged at heading. Samples of these panicles were collected at 3-day intervals after heading and germinated immediately in a germinator at 30°C in petri dishes. Seeds not used were stored in the germinator at 30°C and subsamples were removed at 2-week intervals and germinated as before.

The results discussed here will only include blackhull red rice and strawhull red rice, both of which exhibit some degree of initial dormancy, and Labelle, which has very little initial seed dormancy.

At harvest (our first sampling time), blackhull red rice was essentially dormant until 30 to 33 days after heading, strawhull red rice was dormant even after 33 days, but Labelle began germinating (25 percent) 27 days after heading.

After storage at 30°C for 2 weeks, blackhull red rice samples harvested at 21, 24, 27, and 30 days after heading produced germination percentages greater than 40, 70, 80, and 90 percent, respectively. Strawhull red rice harvested at these same times germinated at greater than 70, 85, 90, and 90 percent, respectively. Labelle harvested 15 days after heading germinated at near 50 percent after 2 weeks storage, and this percentage increased to 75 to 80 percent for samples harvested at 21 to 30 days after heading.

It was concluded that strawhull red rice was slightly more dormant initially than blackhull red rice, both of which were much more dormant than Labelle. Under storage conditions of 30°C in the dark, this initial dormancy started declining after 2 weeks. To reach 50 percent germination, it took blackhull red rice 3.5 to 4 weeks, and strawhull red rice 6 to 8 weeks, whereas Labelle would germinate at 50 percent or greater in 2 weeks. Labelle, blackhull red rice and strawhull red rice are viable 12, 15, and 18 days after heading, respectively.

A third phase of our research concerned the change in color of the pericarp with maturity in blackhull red rice. Grains from blackhull red rice were observed to start changing color (turning dark) about 9 to 12 days after heading. This color change starts in the terminal spikelet and moves randomly throughout the remainder of the panicle.

Using samples from the previous study, grains from panicles obtained at 3-day intervals were divided into dark, intermediate, and green. The number of empty pedicles was counted to obtain a measure of shattering. These values were used to determine the percentage dark, percentage intermediate, percentage green, and percentage shattered.

As blackhull red rice matures, the percentage dark hulls increases, the percentage green decreases, and the percentage shattered increases.

The percentage shattering with maturity was also calculated for strawhull red rice. As maturity increases, percentage shattering increases until, at 33 days after first heading, 50 percent of the grain have shattered.

In conclusion, blackhull and strawhull red rice germinate and emerge more quickly and from greater soil depths than the 5 rice cultivars studied. Strawhull red rice is slightly more dormant initially than blackhull red rice, both of which are more dormant than Labelle. Labelle is apparently viable 12 days after heading, blackhull red rice after 15 days, and strawhull red rice after 18 days. For both red rice types, percentage shattering increases with maturity, and in blackhull red rice this is associated with a darkening of the pericarp.

#### Literature Cited

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## ADDITIONAL RED RICE RESEARCH IN TEXAS

E. Ford Eastin

As pointed out in a previous paper (4), we are taking a little different research approach to red rice in Texas than are some of the other states. In addition to evaluating herbicides for red rice control, we are trying to look at some of the more basic, or fundamental, aspects of this weed in order to gain some leads for possible control measures. Most people agree that red rice is the same species as our cultivated rice (*Oryza sativa* L.); therefore, we will have to find a herbicide or practice that is very selective in order to be able to control red rice without injury to white rice. Crop rotation into another crop such as sorghum or soybean is one alternative that we suggest, as this is the only method we have to get really good control of red rice and thus work toward eliminating this weed in a field. We do not have any good way to clean up red rice in rice. We must rotate out of rice and use control methods that are available in the alternate crop.

We are looking at some basic characteristics of red rice at this time, particularly dormancy and germination. I feel that one of the main factors influencing red rice persistence is its dormancy, its ability to remain viable without germinating.

Some of the first studies we conducted concerned the effect of temperature on germination of blackhull red rice as compared to 22 U.S. rice cultivars or varieties. Seed were put in petri dishes with filter paper and distilled water and placed in incubators at 15°, 20°, 25°, 30°, 35°, and 40°C (59°, 68°, 77°, 86°, 95°, and 104°F). Germination was counted daily for 7 days. To summarize this work, the lower limit of germination was between 15° and 20°C, with 40°C being detrimental to germination. The optimum temperature for germination of blackhull red rice was 30° to 35°C, compared to 30°C for the cultivars. We received almost complete germination at temperatures above 20°C for blackhull red rice, but it germinated faster at the optimum temperature. Another way to summarize these results is that, given any temperature, blackhull red rice germinated 1 day earlier than the cultivars or, on any given day, blackhull red rice germinated at 5°C (9°F) lower than the cultivars.

We then decided to try some chemical treatments to determine if we could influence red rice germination at reduced temperatures. A temperature of 20°C, and chemical concentrations of  $10^{-3}$  to  $10^{-7}$  M (molar) were used on both non-dormant



blackhull and non-dormant strawhull red rice. The chemical treatments used were 2,4-D, ethephon, gibberellic acid, indole-3-acetic acid and kinetin, which are either natural or synthetic growth hormones; proline, an amino acid that has been shown to increase germination and seedling growth; hydroxylamine, sodium nitrate, and thiourea, which have been shown to affect germination in some types of seed. To summarize this study, none of the treatments influenced the speed of germination of either red rice at 20°C.

Since dormancy in rice seed has been reported to be controlled by volatile compounds in the seed hull, we treated red rice with hydrogen peroxide, a strong oxidizing agent. If the compounds responsible for dormancy are oxidized, dormancy should be broken. Both dormant and non-dormant blackhull red rice were treated with 0.1, 1, 10 and 30 percent concentrations of hydrogen peroxide for 15 minutes, then germinated in distilled water at 30°C. The treatments did not increase germination of the dormant seed nor did they reduce germination of the non-dormant seed.

Another series of experiments concerned the effect of storage temperature on dormancy of red rice. In these experiments fresh, dormant blackhull red rice seed were used. They were stored at 40°, 45°, and 55°C. Samples were taken at intervals, put in petri dishes with water, and germinated at 30°C, to check for dormancy. Chang and Bardenas (3) recommend breaking dormancy on freshly harvested rice seed by putting it in a 50°C oven for 4 to 5 days. Jennings and de Jesus (5) indicated it took up to 7 days to break dormancy on seed that had a severe dormancy. There was no difference in germination at the various storage temperatures for up to 6 days in our blackhull red rice. Differences showed up after 7 days; and after 15 days the 55°, 45°, and 40°C storage temperatures resulted in about 55, 40 and 30 percent germination of red rice, respectively. Breaking dormancy has been defined as at least 80 percent germination (5). This test was terminated after 15 days at which time 80 percent germination had not been achieved. Since this study was twice as long as the study by Jennings and de Jesus (5) to break severe dormancy in rice, it can be concluded that this red rice exhibited a very severe or strong dormancy.

In a companion study, the same seed source was stored at 2°, 24°, 30°, and 35°C. Samples were taken weekly for 12 weeks to determine germination. After 12 weeks, red rice stored at 2°, 24°, 30°, or 35°C had 1, 55, 80 and 95 percent germination, respectively. The higher the storage temperature, the quicker dormancy was broken.

In another experiment both blackhull and strawhull red rice seed were collected 5 weeks after heading. Data from a previous study by Helpert and Eastin (4) indicate good viability and dormancy 18 to 21 days after heading, so this seed source had overripened in the field about 2 weeks. This seed was stored at temperatures of 40° to 60°C and sampled at 2-day intervals. In this experiment both blackhull and strawhull red rice responded similarly at all storage temperatures. These seed started breaking dormancy immediately at 40°C or above. In other words, we had about 25 percent germination after 2 days which went on up after 8 days to 80 percent germination. Thus, we found that differences in seed lots and the time after heading of the red rice at harvest may affect dormancy. If dormancy is controlled by volatile compounds in the hull, as these compounds volatilize out and leave the hull, dormancy will be broken. In this seed source, these compounds had already begun leaving the hull so that it did not take as long to break dormancy as with the previous seed source.

We tried chemical treatments on dormant and non-dormant blackhull red rice. Some of these treatments were a repeat of earlier studies. We used blackhull red rice, with the chemicals at  $10^{-3}$  to  $10^{-7}$  M and incubators at 30°C, and counted germination daily. In preliminary studies with the dormant seed, none of the treatments evaluated had any effect on breaking dormancy. With the non-dormant seed, we had no effect from triacontanol, adenosine 5'-monophosphate, adenosine 3':5'-cyclic monophosphate, and adenosine 5'-triphosphate. Non-dormant seed incubated in  $10^{-3}$  and  $10^{-4}$  M coumarin germinated, and the radicle emerged through the seed coat or hull but did not grow. Concentrations of  $10^{-3}$  M 6-benzylamino-purine completely inhibited germination of non-dormant red rice seed. Abscisic acid at  $10^{-4}$  M slowed the speed of germination and at  $10^{-3}$  M induced dormancy. This compound has been reported to induce dormancy in several plants and has been proposed as one of the primary causes of dormancy in rice seed.

In growth-chamber experiments we have studied 10 acetanilide herbicides, which are similar to Dual and Lasso. We used 4 rice cultivars, LaBelle, Star-bonnet, Brazos, and Nato. We also used Labelle and Brazos, treated with 1 percent naphthalic anhydride, and blackhull and strawhull red rice. Each sample was placed in growth pouches and treated with various concentrations of the herbicides. Dry weight was determined after 2 weeks. In summary, there were differences in cultivar responses to a herbicide; in other words, one variety may be more tolerant to a herbicide than another variety. There were also differences in herbicide response; that is, one herbicide may be more toxic than another. The

naphthalic anhydride did afford some protection in some cases, but we were not able to get 100 percent protection. This agrees with reports of Baker and Bourgeois (1,2) using thiolcarbamate herbicides.

Our field evaluations of herbicides for red rice control have concentrated on soybean and sorghum herbicides. Soybean preemergence herbicides were surface applied in our tests, but we usually encourage incorporation for consistent control. In this 1978 study, timely rainfall activated the surface-applied herbicides. Herbicides that gave 90 percent control or better were Lasso at 3 to 4 lb/A, Dual at 2 to 3 lb/A (Dual is similar to Lasso but is active at a lower rate), and Antor at 3 to 4 lb/A. Most of the other soybean preemergence herbicides we evaluated, such as Sencor, Lexone, and Lorox, did not give this level of control. A herbicide such as Sencor or Lexone can be added to Lasso or Dual to increase activity against broadleaf weeds. There will be very few times when you have only one weed species in a field. We are talking primarily about red rice today; however, to be practical we cannot forget the other weeds. In other words, we have not come up with the miracle herbicide yet that will control all the weeds and not injure the crop.

We applied postemergence herbicides just as the red rice was starting to tiller, and again we need to remember that these results are from over-the-top applications. Paraquat at 0.125 lb/A gave excellent control. Hoelon, a slow-acting herbicide, gave good control after 4 weeks. Lorox, plus a surfactant, at 1 lb/A also resulted in good red rice control. Paraquat and Lorox must be post-directed, whereas Hoelon can be used over-the-top, but they do not give as good control as paraquat post-directed. If the soybeans are up to any size at all, we may have trouble killing the red rice in the row because the soybeans will shade it out. If we use herbicides over-the-top, we may not get complete coverage and we will not get complete control of the red rice. Control is usually not as good if the red rice has started tillering. Just as Arkansas studies suggest, the best postemergence control of red rice in soybeans would probably be obtained with a double application of paraquat, 0.125 lb/A on 8- to 10-inch soybeans and again in 7 to 10 days. This should clean up red rice that preplant or preemergence herbicides fail to control.

An experimental over-the-top postemergence combination that looks very good in soybeans is Vistar (a 3M herbicide called MBR-12325 or Embark) plus Basagran plus a surfactant. When applied to red rice that is just starting to tiller (or earlier) at rates of 0.125 lb/A Vistar plus at least 0.5 lb/A Basagran or 0.25

lb/A Vistar plus at least 0.25 lb/A Basagran, this combination resulted in excellent red rice control. Neither of these chemicals by itself will control red rice. Basagran is actually labeled for use in rice for control of some broadleaf weeds, and Vistar will stunt the red rice and may inhibit heading a little if applied just prior to heading, but neither will control red rice by itself. If you put them together, however, even at these low rates, they will do an excellent job.

We have evaluated several triazine preemergence sorghum herbicides for red rice control. Those that gave the best red rice control were atrazine, propazine (or Milogard), and cyanazine (or Bladex) at the maximum label rates. Lower rates resulted in less control. These herbicides were preemergence surface applied with timely rainfall; however, for consistent results we suggest preplant incorporated application, because if most of these herbicides go 2 weeks without rainfall after surface application they give inadequate red rice control. They may still control pigweed or other easy-to-control weeds, but red rice is one of the more tolerant weeds controlled; thus a small or moderate loss of the herbicide may result in inadequate control.

To summarize, I will admit we do not have all the red rice answers but we do have some approaches that will work. With our present technology, it is safe to say we must rotate our red rice fields out of rice into an alternate crop such as soybean or sorghum. We do have systems that will work in these crops. It is not going to be easy, but as Arkansas says, we can "get the red out."

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## RED RICE CONTROL IN TEXAS

Arlen D. Klosterboer

Texas rice farmers have recently become extremely concerned about red rice control. It is apparent that each year a greater number of rice acres become infested with this troublesome weed. Although there are many factors that have contributed to this increase, the most important are more intensified use of land for rice production, movement of machinery from field to field, the long dormancy period of red rice, and the introduction of red rice in seed rice.

Red rice infestations are difficult and expensive to control; this troublesome weed costs Texas producers an estimated 5 to 10 million dollars each year. Infestations can be so bad that fields may not be harvested at all. Losses result not only from reduced production but also from reduced quality.

The purpose of this presentation is to provide some recommendations or guidelines for controlling red rice in Texas. Rice farmers cannot depend on one or two practices to effectively control red rice. Control requires a program approach that emphasizes good management. A combination of preventive, cultural, and chemical methods in conjunction with crop rotations is needed.

The preventive measures that can be used are planting high-quality seed and using clean equipment and machinery in farm operations. Only those farmers that do not have red rice or those that want to prevent the spread of red rice to noncontaminated fields are likely to use these preventive measures.

The use of high-quality rice seed free of red rice is extremely important in preventing the introduction of red rice into a field. Purchasing seed rice with red rice could be one of the most expensive purchases a farmer makes. There may be many instances in the Upper Gulf Coast where red rice was introduced into an area with the seed rice. Another preventive measure that farmers should consider is the use of clean machinery and equipment. It is important that farmers, after working in a red rice infested field, whether during field preparation or harvesting, use all means available to prevent the introduction of red rice seed into fields free of red rice. Mud and other debris that cling to tractors and cultivating equipment may contain red rice seed and be moved into a clean field. Transporting combines that are not properly cleaned following harvesting of red rice infested fields is one way that red rice can be spread to previously clean fields.

In addition to preventive practices, certain cultural methods can be used to control red rice. During seedbed preparation, it is important to remove all red rice plants from the field prior to planting. If red rice is permitted to get a head start on commercial rice, it is difficult for the commercial rice to remain competitive. Red rice is more vigorous and faster growing than commercial rice; therefore, every attempt should be made to give the commercial rice an opportunity to compete effectively with the red rice by removing all weeds and red rice from fields prior to planting.

It is also important to plant at the recommended seeding rate. Planting at the suggested or slightly higher seeding rate gives the commercial rice a competitive advantage. Red rice tillering and seed production are decreased, reducing the possibility of increased infestations of red rice.

Proper water management can be used effectively to suppress red rice. The least desirable water management program is one in which the rice is planted, flushed, and drained immediately, and then flushed only when the rice needs water to grow. Permitting the soil to dry out and rewetting on a cyclic basis is very conducive to weed and red rice seed germination. Keeping the soil as wet as possible without adversely affecting commercial rice growth is beneficial.

Water seeding in combination with good water management can be used as a means of suppressing red rice. A suggested technique is to plant sprouted seed into the water and then drain the field. Prior to flooding, all vegetation should be removed to assure that there is not any red rice actively growing at the time the rice is planted. The field should be reflooded within 5 to 7 days or whenever the rice has a small root developed to permit adequate growth. Flooding is maintained at relatively low levels after the rice has become established to permit the commercial rice to grow normally.

A cultural practice that is extremely expensive, but which can provide some control, is continuous fallow. This refers to disking the field each time a stand of red rice emerges. The periodic disking of the field will reduce the reservoir of seed; consequently, there should be less red rice in following years. Fallowing requires at least 4 to 6 diskings per year. Following each cultivation, the soil should be packed to provide a good seedbed to assure red rice seed germination. To be effective, fallowing must be continued for 2 years.

The most practical and economical means of controlling red rice is to rotate grain sorghum and/or soybeans with rice. Two suggested 3-year crop rotations are soybeans, soybeans, rice or grain sorghum, soybeans, rice. The latter rotation

may be better adapted to the area west of Houston, and the former east of Houston. Since the herbicides used in grain sorghum have label restrictions regarding the length of time between application and planting of rice, it is necessary to plant grain sorghum the first year in the 3-year rotation. When growing soybeans in these rotations, it is important to utilize a herbicide such as Lasso at 3.5 to 4.0 pounds per acre or Treflan at 1.5 to 2.0 pounds per acre, depending on soil type. Another herbicide that has demonstrated a potential for control of red rice in soybeans is Dual. At rates of 3.0 pounds per acre, it has provided excellent control of red rice. It is necessary to incorporate Treflan prior to planting, and it may also be advantageous to lightly incorporate Lasso and Dual with a field cultivator or spike tooth harrow to ensure activation of the chemical, particularly if dry weather is anticipated. Planting grain sorghum in the rotation and using either atrazine or Milogard may be more effective than using herbicides in soybeans. Although red rice can be controlled with these herbicides, early cultivation and application of post-directed herbicides to control any red rice that escapes the soil-applied herbicide is necessary. It is important to plant the alternate crops for at least 2 years prior to rice to achieve satisfactory control. It may also be necessary to repeat the 3-year rotation after the initial 3-year rotation.

Although roguing and stubble burning can be done, it is questionable whether they are practical and feasible. Roguing can be used where there are only a few red rice plants scattered through the field. If one plant is permitted to mature, it can lead to an infestation of several hundred plants within a few years. Stubble burning is not very effective since the soil does not get hot enough to destroy many seeds. It only affects those seeds that are exposed above ground.

In summary, farmers must take a program approach in controlling red rice. It will require a combination of both cultural and preventive practices with crop rotations. Since there is no herbicide that will satisfactorily and selectively control red rice in commercial rice, farmers must rely on these practices to control red rice.

## CONTROLLING RED RICE IN LOUISIANA

Lewis C. Hill

For many years red rice has been allowed to build up in rice fields in Louisiana. One of the main reasons for this is that red rice is extremely difficult to control. No quick and easy method is readily available. There are, however, several methods which may be used in combination over several seasons that will significantly reduce red rice infestations. These methods include fallow plowing, using red-free seed, certain water planting methods, rotation with other crops, roguing where there are only a few red rice plants in a field, and cleaning machinery and equipment.

Fallow plowing alone may be used to control red rice by some farmers who can afford to leave the land idle. The most common method used in fallow plowing is to work the land early and run a cultipacker over the field as a last operation. When a stand of red rice emerges, it is destroyed by cultivation and firmed again with a cultipacker or land plane. This operation is repeated as often as the weather allows. Where fallow plowing is practiced over a period of 2 years, substantial amounts of red rice are destroyed unless unusual weather prevents a reasonable number of plowings.

The use of red rice free seed is another method of control that is often neglected. Farmers with red rice problems sometimes feel that it doesn't matter if the seed to be planted has a little red rice in it. This, of course, leads to further plantings of red rice. If there is only one red rice seed per pound and a farmer plants 135 pounds of seed per acre, this gives him 135 fresh new red rice plants per acre. Consequently, buying red-free seed would have to be considered essential, regardless of the existing red rice population, if any control measures are to be effective.

Certain water planting methods are helpful in controlling red rice. The two most successful methods are continuous flooding and pinpoint flooding. These two methods keep the red rice seed soaked, which prevents them from germinating. Other methods have not proven to be very beneficial.

When using the continuous flood method, the land is first prepared well enough to completely destroy all existing vegetation. Some producers work the field extremely well. Others leave the fields with small clods. There is usually more seedling movement during high winds when the field is smooth than when it is allowed to remain slightly rough. Following preparation, the field



is flooded with a full flood. The field may be dragged following flooding using a harrow or similar tool. The seed, either presprouted or dry, are sown into the floodwater. The full flood is held and the plants allowed to come through the floodwater. The field is not drained until the normal draining operation prior to harvest. The continuous flood method has not been used extensively because obtaining a satisfactory stand is uncertain.

When the pinpoint method of flooding is used, the land is worked well to destroy vegetation and to prepare a good seedbed. The field is then flooded. Again, as in the continuous flood, the land may be left slightly rough. The dragging operation may or may not be used. Dragging seals the soil and helps prevent germination of weeds but leaves the field so smooth that the rice seedlings may be washed out of place as mentioned above. Where the field remains in small clods, the rice seedlings may be held better by the soil. The next operation is to sow the seed into the floodwater. After seeding, the field is drained if presprouted seed are used, or left for the seed to crack if dry seed are used. In either case, the small rice plant is allowed to peg down into the soil with about an inch of root. After pegging down, the flood is started and gradually increased as the rice plant develops. This allows a full flood by the time the rice plant is able to take it.

Pinpoint flooding is a compromise between the continuous flooding system and normal rice culture. The continuous flooding system offers the greatest red rice control, while the pinpoint method gives a better chance for a good stand of rice and still affords a significant degree of red rice control.

Ordram properly incorporated at a rate of 3 pounds per acre has shown some promise as an aid to controlling red rice in water-planted rice. For best results, the Ordram must be incorporated immediately into a well-prepared seedbed. The floodwater must be applied right behind the incorporation of the Ordram. The pinpoint flooding method should then be employed. If this method cannot be used, flooding should be done at the earliest date possible. If flooding is unduly delayed, flushing may be necessary. The range of control by Ordram of red rice emerging in any one year may vary considerably. When applied according to the label, Ordram should not have any appreciable residual for crops in following seasons.

Another method of red rice control is crop rotation. In Louisiana, soybeans are usually rotated with rice. This combination effectively controls red rice if it is handled properly. Using effective herbicides and fallow plowing prior to planting soybeans increase the control of red rice in soybeans.

Most of the herbicides used to control weeds in soybeans have some activity on red rice. Some are much more effective than others. Selection of these herbicides should be carefully made so that the greatest benefit may be derived from both preemergence and postemergence activity. Soybeans planted in rows offer the greatest opportunity to get the most from herbicides in controlling red rice, since this planting method allows for post-directed sprays. In addition, if the herbicides used require moisture for activation, soybeans in rows may be cultivated if there is not enough moisture to allow the herbicide to work.

Most soybeans are planted in May in Louisiana. This allows from one to three cultivations to control red rice prior to the planting of soybeans, if the weather cooperates. Using this approach, the soybean land is prepared well at an early date. The last tool over the field in the preparation operation should be a cultipacker. This firms the soil and encourages a uniform stand of red rice to emerge. Following the destruction of each succeeding stand of red rice, the same cultipacking operation should be repeated. If soybeans are kept on the field for 2 years and the weather allows it, as many as six crops of red rice can be destroyed with cultivation.

Where rice is planted on clean land, even with the best of seed, a few red plants may be present. These few red rice plants should be carefully rogued. This means taking the whole plant out and destroying it. If a few tillers are left, they will produce seed. If the red rice has headed, the plant should be completely removed and burned since the red seed will develop enough to germinate in a very short time following pollination.

When moving machinery from a field heavily infested with red rice, the machinery should be carefully cleaned to avoid further contamination of fields. Other farm equipment should also be inspected and cleaned as needed. When dryers are emptied, they should be cleaned before being filled with different lots.

Controlling red rice can give increased yields and better quality. It will also save on labor costs and give the individual farmer more time for attention to other problems. The local county agent should always be consulted for the latest information on red rice control.

## RED RICE CONTROL PROGRAM FOR ARKANSAS

Bobby A. Huey

Even though research findings and recommendations for red rice control are a part of any presentation given to Arkansas rice farmers, I want to try to avoid that aspect as much as possible since others have covered it adequately. What I want to discuss is the gap between what research has demonstrated can be done and what Arkansas rice farmers are actually doing to control red rice. We think there is a gap and, of course, the Extension Service is charged with disseminating research results and recommending their use. I think we have a directive to try to close that gap. I want to cover some of the ways we are motivating farmers to get the job done. We are trying to do things other than just providing information; we are trying to get it used.

I think the first motivating principle is that red rice is going to cost you (the farmer) money, and if you believe that strongly enough, and it costs you enough, then it is easier to spend the money for control. Control is difficult and it is going to cost--let there be no doubt about it. Red rice will cost you in a number of ways. For example, yield loss occurs when the red rice infestation is so bad that lodging occurs. Lowered quality of harvested rice is another loss for the producer, since it results in discounts and lower money returns. Money not received must be recognized as a cost of growing red rice. Red rice also affects quality by reducing the head rice yield, the most valuable part of the rice crop. This means that somewhere down the line, the price you receive for the rice is going to be lower. So, there are three costs--yield loss and two aspects of quality loss. In 1975, we had difficulty selling rice when we expanded production dramatically. Many buyers were not buying Grade 3 or lower. This will really get your attention if you have a perfectly good crop except for some red in it, which reduces it to No. 3 or lower.

Still another cost is the increased cost of weed control. Most aspects of the control program involve extra costs. So, if you really believe the returns will exceed cost of control, we feel you will be motivated to initiate some control measures. If you delay until infestation is heavy enough to cause rice to lodge before grain is formed, you will know for sure red rice is bad enough to treat, but at this stage losses will be great despite any control measures taken. Concerning red rice control in dry-seeded white rice, Dr. R. J. Smith, Jr. has experimented with a safening agent for Ordram PPI. He was able to get only about

60 to 70 percent control. We never felt that this was quite good enough. The best control in the rice crop is with PPI Ordram for water-seeded rice and a continuous flood.

A unique method we use to illustrate the cost of red rice on a state basis is making available information from the milling industry, concerning discounts and reasons for these discounts. We did a study in 1974, 1976 and 1977. We feel it is important to establish benchmarks to measure the size of the problem, and if we ever make any progress, we can go back to actual records and measure the amount. This is quite important in accountability of Extension and Research programs. Showing Arkansas losses amounting to \$0.5 million annually in discounts was one benefit of this effort; however, most farmers could care less what red rice is costing the state. It is the cost to individual farmers that is really uppermost in their mind, so we use other ways to get at this. Occasionally, we will go to the mill and select lots that have been discounted. For example, in 1977 Farmer X had a lot of rice with 8.6 percent red rice grading No. 6. This would figure out to be 29 acres of rice discounted enough to purchase about 1/3 of the cost of a pickup truck--a value he can relate to. Sometimes this gets the message told about cost.

We also survey farmers. This gives them a chance to express their concern about certain weeds and gives us some data about the size of specific weed problems. The last one that we did was in 1976. Red rice infested about one-third of a million acres (one-third of our rice acreage in Arkansas), and I suspect that if we had repeated the survey in 1978, it would be higher.

We do another little trick that is of interest. We rank the top ten counties in red rice production, which creates some interest among our sports enthusiasts. Arkansas County grows about 110,000 acres of rice and is our current leader in red rice production with Lonoke County a close second. Lonoke County has a large fish farming business which has crowded their rotation, making red rice worse. These two counties usually alternate as the leader in red rice production.

We also prepared something to refute the idea, "A little red won't hurt much." With help from Dr. Smith, we figured that one red rice plant per acre, with 10 tillers and 150 seed per panicle with 100 percent germination, would produce 1,500 seed per acre the first year. If this could be evenly distributed over an acre and the same assumption made; theoretically, a planting rate of 135 lb/A of red rice would be produced in 2 years beginning with one plant per acre. So, a little is too much.

We try to expose the attitudes: (1) "A little red in planting seed will not hurt much." (2) "I buy seed that is certified or subject to certification" (we tell them that is like buying a bird dog "subject" to registration). (3) "I have some in the field, but they did not give me a discount." Farmers brag about this in Arkansas, but what about the seed in the soil? (4) "There is no control." We really work on number 4 because there is control. It is just not easy. Of course we deal with the systems approach all the way through, and you will notice that one method we do not use is summer fallowing. We are all either too poor or too greedy to leave the land out of production. We are going to have to try to control red rice in a crop and still get an income off the land.

We talk to farmers about the keys for identifying certified seed. In Arkansas seed should be bagged and tagged. This drives the seed dealers up the wall because they sell a lot of rice that is not in a bag. It is sold in bulk as "field certified." Nevertheless, if you have bagged and tagged rice, only then can you be assured that it has passed both field and bag inspection and that what is in it is on the tag. We have a tolerance in Arkansas of one red rice seed per 2 pounds, which may be a little too much. We may need to change this. However, seed dealers say the cost will be too high if we make it stricter.

I would like to discuss some cultural controls not mentioned today, such as the elimination of potholes. A state plant board field inspector will go directly to the pothole for inspection, because that is where he is going to find red rice. We can eliminate the perennial sources of red rice production by filling the potholes. We need to eliminate the potholes anyway.

When tillage is done, we want to be sure to smooth the soil to enhance germination, then destroy as many crops of red rice as possible before planting. We like to roll the rice stubble in the fall instead of plowing it. Sometimes we flood it for duck feed. Another cultural method is water seeding. We have recommended Ordram preplant-incorporated in water-seeded rice for a long time. It has been something of a "back door" recommendation which the manufacturer has always worried about. There has been a national label for preplant incorporation of Ordram for barnyardgrass control to which the Arkansas Extension Service added comments that it would suppress red rice. We know that it will work, based on Dr. Smith's data. If you can work out the water management, which is an art instead of a science, using preplant incorporation of Ordram and a continuous flood, you can expect 70 to 80 percent control.

Dr. Smith has developed research data showing the value of Ordram in a continuous flooded culture. He has improved the control of red rice by adding Ordram



to the practice. So we, like Texas and other states, promote the idea that if you must put a red rice infested field in rice production, you need to develop the art of stand establishment with water seeding and Ordram preplant incorporated for control. It is the best and only control program we have for the rice crop. So there is control, if control methods are properly used.

We also use a cultural practice in soybeans that one of the farmers alluded to earlier. If you have done the best you can and have failed, and you see red rice out there in the field, take a disk to it, because otherwise you are going to lose a whole year in the rotation program. The entire control effort is based on the principle of using up the red rice seed. We want to create situations where as much of it will germinate as possible. Then we want to destroy it before it has a chance to reproduce itself. This is the whole idea of getting a badly infested field out of rice and into a rotated crop where control is possible.

In Arkansas, we had a successful program, developed by Dr. Ford Baldwin called "War on Cockleburs in Soybeans," a few years ago. We have patterned a similar program after it, entitled "Get the Red Out." We are trying to dress it up with posters and cartoon characters--anything that we can do to create interest in getting the red out. We are preparing a lot of material for this program. We have already prepared a leaflet (EL 604) specifically on red rice control that we hope will add emphasis to the effort.

We have talked to industry all the way up in an effort to overcome the idea of some farmers that "the rice mills ought to do something about red rice control." The problem is on the farm and the solution, if there is one, will be on the farm. We have work to do in all phases of the industry to get total support for a good red rice control program. We encouraged extension agents in all 42 rice-producing counties to establish field demonstrations. This is different from testing herbicides in strips across a field. We are not asking them to check out herbicides, and we are not going to give them any free herbicides to check. What we are trying to do is to demonstrate that we have the technology for red rice control now. We try to get everyone that has a bad red rice problem to use it. Hopefully, they can at least find one of the worst fields in the county and go through the two 3-year rotation cycles, if necessary, to show that a bad situation can be turned into a good one. We think this can be a valuable educational tool.

In summary, we have some good research and we have some good programs, but there is a gap between what research says can be done and what farmers are doing. Extension of research into that gap is needed. All of the ideas and programs we have and all the demonstrations and plans sound good. Why is it that Arkansas is

probably now the leading red rice producing state in the nation? It is getting worse, not better, each year. I really do not know why, but I have some ideas and I would like to pass them on. Why is red rice infestation increasing? I suggest that you consider a few of these problems: (1) Many people delude themselves with the attitude that money not received is not money lost. (2) Red rice control is difficult and requires long-term control measures. We have never before had to get after a weed pest like red rice requiring one 3-year cycle if infestation is just mediocre, or two 3-year cycles if it is really bad. It is difficult to stay after a problem this long. (3) A lot of people know that they have red rice but think that they can get by. (4) It is difficult to get good clean seed in Arkansas today and even more difficult to know that the seed you purchase is clean. (5) Greed is a factor that exhibits itself in two forms. One is greed on the part of the landlord, who wants as much rice grown as often as possible for high-rent payments. Some landlords want rice every other year. Some owners are not even aware of red rice, its control, or of rice farming practices. They own the land and can demand half of it seeded to rice. If the tenant does not comply, there is another farmer just down the road eager to rent him out. Then we have greed on the part of the producer wanting to grow as much as possible, who thinks in terms of the short-term and not the long-term effects. (6) We also have what I call "mismanagement." If we review the management history of farms with severe red rice problems, it generally reveals farmers that have the least control over their management. Ten or twelve years ago, if you went to the farms that had the greatest red rice problems in Arkansas, it would be people that had more allotment than they had land to rotate. In fact, one area that had an early red rice problem was where they were building canals and growing minnows for fish in Lonoke County. This created tremendous problems because it just squeezed the rice land to fewer and fewer acres.

I think there is one last reason for the red rice problem in Arkansas that I have failed to mention--we have learned to irrigate soybeans better each year. If you have a little red rice and go to extensive soybean irrigation during a dry year, you will likely stimulate red rice production by timely irrigation, resulting in bumper crops of both red rice and soybeans. Finally, I think it is clear that the red rice problem is at the farm level and that the solution can be worked out by the farmer if he will use the control programs already developed by research personnel.

APPENDIX

Common, Trade, and Chemical Names of Herbicides  
Referred to in the Text

Common Name	Trade Name	Chemical Name
alachlor	Lasso	2-chloro-2'-6'-diethyl-N-(methoxymethyl) acetanilide
atrazine	AAtrex, Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine
bentazon	Basagran	3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one-2, 2-dioxide
cyanazine	Bladex	2-[[4-chloro-6-(ethylamino)-s-triazin-2-yl]amino]-2-methylpropionitrile
2,4-D	several	(2,4-dichlorophenoxy) acetic acid
diclofop-methyl	Hoelox	methyl-2-[4-(2, 4-dichlorophenoxy) phenoxy] propanoate
fluchloralin	Basalin	N-(2-chloroethyl)-2,6-dinitro-N-propyl-4-(trifluoromethyl) aniline
linuron	Lorox	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
mefluidide	Vistar	N-[2,4-dimethyl-5-[[[(trifluoromethyl)sulfonyl]amino]phenyl] acetamide
metolachlor	Dual	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide
metribuzin	Lexone, Sencor	4-amino-6-tert-butyl-3-(methylthio)-s-triazin-5(4H)-one
molinate	Ordram	S-ethyl hexahydro-1H-azepine-1-carbothioate
paraquat	Paraquat CL	1,1'-dimethyl-4,4'-bipyridinium ion
pendimethalin	Prowl	N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine
profluralin	Tolban	N-(cyclopropylmethyl)- $\alpha,\alpha,\alpha$ -trifluoro-2,6-dinitro-N-propyl- <i>p</i> -toluidine
propazine	Milogard	2-chloro-4,6-bis(isopropylamino)-s-triazine
trifluralin	Treflan	$\alpha,\alpha,\alpha$ -trifluoro-2,6-dinitro-N,N-dipropyl- <i>p</i> -toluidine

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