Iron Deficiency of Rice

crop failures in localized areas within productive fields corrected in tests conducted in Glenn and Colusa counties

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Experimental applications of ferric sulfate to nonsaline alkali spots in rice fields have greatly increased yields.

Failure of rice in alkali spots—limited areas within otherwise productive fields—has been a problem for a number of years. In some instances, the spots are on soils that are clearly alkali and where other crops such as barley, sugar beets and safflower also fail. In different spots, nonirrigated barley and other crops grow reasonably well, but rice dies when planted in the same areas.

However, in the fall of 1953 almost all the rice died in a field on a ranch eight miles south of Grimes. Only a strip of excellent rice existed along the course of a narrow slough meandering through the field. Normal growth of previous crops of barley on the same land had been reported. Preliminary examination of the soil where the rice had died showed no appreciable salinity because the conductance was 1.23 millimhos per centimeter, much below the 4.0 value considered to be the lower limit of salinity. Neither was it an alkali soil because it had only 5% exchangeable sodium as compared to the 15% commonly used as threshold value.

Effectiveness of 500 pounds per acre of ferric sulfate broadcast on a rice field just prior to planting is shown by the vertical strips through the field. The carry-over effect from treatment the previous year is shown by the horizontal strips crossing the vertical strips.

Soil Samples Tested

Samples of the good rice soil and of the bad rice soil were taken to Berkeley for nutritional studies in the greenhouse and for chemical analysis in the laboratory. The standard fertility assay for nitrogen, phosphorus and potassium was set up in the greenhouse in the spring of 1954 on both good and bad soils. Half of the pots in each treatment were planted to barley and half to rice.

Barley plants grew well in the surface foot of both types of soil, showing only a nitrogen deficiency in the good soil and nitrogen and phosphorus deficiency in the bad soil.

Rice plants grown under flooded conditions germinated well in both good and bad soils. In the good rice soil plants showed only a slight response to added nitrogen. In the bad rice soil plants rapidly became chlorotic and within five weeks nearly all died, regardless of fertilizer treatment. When not flooded, the rice plants remained alive on the bad soil.

Since no major nutrient was responsible for rice failure, foliage sprays with the several micronutrients were made. Repeated sprays with iron tartrate caused a greening of the plants grown on the bad soil.

Soil treatments with ferric sulfate, ferric tartrate and Versenol, a commercial product containing 4% iron derived from an iron salt of HEEDTA—hydroxyethyl ethylene diaminetriacetic acid—kept plants green and healthy.

Later greenhouse studies showed that iron deficiency did not occur if the soil was acidified prior to planting. The studies also showed that surface broadcast treatments with granular ferric sulfate gave correction at lower rates of application than did finely ground ferric sulfate mixed with the soil.

Field Tests

Field treatments were begun in Colusa County and adjacent areas in Yolo County in the spring of 1955. Soil treatments were made with iron chelates, commercial agricultural ferric sulfate—21.0% iron—at 1,000 and 2,000 pounds per acre and technical ferrous sulfate—19.9% iron—at 1,000 pounds per acre. All materials were broadcast upon a rough cloddy seedbed. The field was flooded and seeded immediately following treatment.

Rice germinated well throughout the entire area but began to turn yellow and the leaves floated upon the surface of the water after about a month. In the areas treated with ferric sulfate, ferrous sulfate and Versenol iron chelate, rice remained green and continued to grow.

By mid-June many of the plants in the untreated area had died and open water remained, with some few plants surviving. These remaining plants recovered in July, tillered well and made a fair crop. At maturity, cut quadrats showed that the yield had been increased from about 1,100 pounds of rice per acre to over 3,700 pounds with the application of 2,000 pounds ferric sulfate. Where 1,000 pounds of material was used ferric sulfate gave a yield of 2,800 pounds, ferrous sulfate 2,500 pounds, and Versenol at 800 pounds per acre gave a yield of 3,000 pounds rice per acre. The results of this first demonstration showed clearly that the failure of rice to survive was related to an iron

Summary of Tests with Ferric Sulfate to Correct Iron Deficiency of Rice

Alkali-saline† classification	Alkali-saline status of soil prior to planting				Location		Yields of rice with ferric sulfate				
	pH values		Salinity ECe millimhos/cm	Exchangeable sodium, %	County	Year	Applications—pounds/acre				
	Paste	1:10 dilution					None	250	500	1000	2000
Nonsaline Nonalkali Normal pH	5.4	6.6	0.46	2	Glenn	1958	good	. . .	good	good	good
	6.6*	7.0*	0.93*	4*	Yolo	1953	good	. . .	. . .	. . .	. . .
	6.2	7.5	0.61	6	Glenn	1958	4758	. . .	5076	4740	4542
Nonsaline Nonalkali High pH	7.6	8.8	1.18	3	Yolo	1958	1625	1937	3583	3792	. . .
	7.8**	8.9**	1.23**	5**	Yolo	1955	1132	. . .	. . .	2827	3765
Nonsaline Near-alkali High pH	8.0	?	1.30	15	Glenn	1957	poor	. . .	fair	good	good
	7.7	9.3	2.05	11	Glenn	1958	2236	. . .	3072	2551	2854
Nonsaline Alkali High pH	8.4	9.4	1.85	39	Colusa	1956	200	. . .	4577	4340	3565
	8.5	10.0	2.20	34	Colusa	1958	500	900	1900	2300	. . .
Saline Alkali High pH	8.9	10.1	4.80	66	Glenn	1958	1410	. . .	1698	1932	2058

† Saline: Conductance over 4.0 millimhos/cm. Alkali: Over 15% exchangeable sodium.

*,** Analytical data on samples of good* and bad** rice soils which gave the first iron responses in the greenhouse in 1954.

deficiency, and could be corrected by applications of iron sulfates—as well as by a suitable iron chelate.

In the spring of 1956 additional demonstrations were set up to test the effectiveness of agricultural ferric sulfate on problem soils. One such test was set up on a known alkali spot on a ranch south of Grimes. Duplicate quarter-acre plots were treated with 500, 1,000 and 2,000 pounds of material broadcast on the surface just prior to flooding. Gypsum at five tons per acre was applied to a small area in one of the untreated areas. Results from ferric sulfate were most striking. Nearly all of the rice in the control and gypsum treated areas died. Yields in the control areas were estimated at 200 pounds per acre. Where treated with ferric sulfate, whether 500, 1,000 or 2,000 pounds, the rice grew well and measured yields of 3,600–4,500 pounds of rice per acre were obtained with a commercial harvester. The following year safflower was planted in the experimental area and died from alkali damage, even in the areas where good rice had been grown with ferric sulfate treatments.

In 1957 a number of strip treatments were made in areas known to be affected with alkali, or on soils where rice had failed following successful crops of barley, sugar beets, or other field crops. In a test on a ranch just south of the Yolo County line the effectiveness of 500 pounds of ferric sulfate broadcast just prior to planting showed clearly as did the second year effect of the ferric sulfate applied in 1956.

A replicated rate test was set up in 1958 on the same ranch and on the areas

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A ferric sulfate plot on a ranch near Grimes. The area on the left was treated with 500 pounds of ferric sulfate to the acre and produced better than 40 sacks of rice per acre. The untreated area is on the right and in the background

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left untreated in the two previous years. Rates of 250, 500 and 1,000 pounds ferric sulfate were applied as long strips, each replicated three times across the affected area. Yields, as measured by a commercial harvester cutting out each strip, were increased from 1,625 pounds per acre on the control up to nearly 3,583 pounds per acre where 500 pounds ferric sulfate were used. On this soil 250 pounds per acre were clearly not enough and no advantage resulted by increasing the application to 1,000 pounds per acre.

Glenn County Tests

Field tests were initiated in Glenn County in 1957 on an alkali area 12 miles east of Willows. Treatments were laid out to compare ferric sulfate with ferrous sulfate at 500, 1,000 and 2,000 pounds per acre and with a treatment of 900 pounds of sulfuric acid per acre. All treatments were crossed with a strip of five tons of gypsum per acre to provide calcium equivalent to the exchangeable sodium in the top 6″ of the soil. No effect of the gypsum and only slight result of the sulfuric acid were observed.

At each rate of application commercial ferric sulfate gave better growth than equivalent iron from ferrous sulfate. No carryover effect of any treatment was observed on rice grown in the experimental area the following year.

Replicated rate tests to determine for each case the effectiveness of ferric sulfate were set out in 1958 on fields with a wide range of alkali conditions. Three plots were harvested. Two showed definite increases in yield of rice from the use of ferric sulfate, with no effect at the third site, where production was good.

There were definite responses to ferric sulfate on a bad alkali spot five miles south of Willows but total yields were low.

On a less severe alkali spot five miles north of Glenn and two miles west of the Sacramento River, striking differences in early growth were observed. By mid-July rice in untreated areas had recovered and at harvest yield increases due to ferric sulfate were only 500–800 pounds per acre.

Soil Conditions

The spots where rice fails because of iron deficiency usually represent from 2–3 acres up to 50 acres. Examination of the soils where responses to ferric sulfate have been observed show a wide variation in alkali status.

The first group of three soils shown in the table on page 7 would be classified as normal nonsaline, nonalkali soils with pH—relative alkalinity-acidity—values in the neutral range, a little above and a little below pH of 7. Rice from these three locations grew normally, produced good crops and showed no response to ferric sulfate. The salinity values ranged from 0.46 to 0.93 millimhos per centimeter conductance. From 2% to 6% exchangeable sodium was present.

The second group of soils upon which striking responses of rice to ferric sulfate were observed are ones where other field crops, such as barley, grow normally. These soils differ from normal soils only in the fact that the pH values increased with dilution to an alkalinity of nearly 9. Also, they show 3%–5% exchangeable sodium and a slightly higher salinity than the soils where rice grows normally. This group of soils may be classified as nonsaline, nonalkali soils with high pH. Carryover effects of ferric sulfate on succeeding crops of rice have been observed on such soils.

The third group of soils contain 11%–15% sodium, with low salinity. These show good responses to ferric sulfate, but little carryover effect. Since percent sodium values were at or below the 15% value these soils are classified as nonsaline, near-alkali soils of high pH.

The fourth group of soils contain higher amounts of exchangeable sodium —30% to 40%—and about the same salinity as the first three groups. They are soils where crops such as barley and safflower fail, but where rice may be encouraged to grow if iron is supplied to overcome iron deficiency. These soils would be clearly classified as nonsaline alkali soils of high pH.

The fifth group, soil both saline and alkali, is represented by a single test. The soil had 66% exchangeable sodium,

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An outstanding response from ferric sulfate in a rice field near Grimes. This area was treated with 700 lbs. of ferric sulfate per acre. Note the skip marks where the easy flow missed.

MEALYBUG

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bined with dormant oil. The same spray equipment was used, and an average of 600 gallons was applied per acre.

With the fall and winter sprays, an attempt was made to determine the percentage kill of crawlers by removing the overwintering cottony egg sacs from the limbs and trunks of the trees. They were brought to the laboratory and examined under a binocular miscroscope in order to determine the number of living and dead crawlers. The plots were finally evaluated by counting the number of damaged fruits at the harvest period in late June.

In Section *C*, the petal fall treatments were applied on March 27. Continuous rains during late February and early March prevented spray applications and the timing of this treatment was late. The inclement weather also affected the mealybugs, as no activity was observed prior to mid-March. The materials used at the petal fall stage were applied without oil, and an average of 650 gallons was applied per acre.

All plots, fall, winter, and spring, were checked for the presence of mealybugs on the fruit at harvest. Six hundred fruits were examined per treatment, and fruit was picked at random from the trees. The fruits with mealybug present, or those showing honeydew and black fungus, were recorded as infested.

In general, the fall and winter treatments were less effective than the spring sprays. The mealybug crawlers are well protected, not only by their location, but by the waxy fibers in the old egg sac, and it is virtually impossible to wet all the colonies. The fall treatments were not as effective as the winter, probably because the presence of foliage made it difficult to obtain bark coverage. The fall and winter counts of crawler mortality did not correlate well with the final fruit counts. The technique of examining colonies was not too feasible, as the number of living mealybugs depended upon how well the colony was protected by the bark. It was not possible to select colonies with the same degree of protection. It was possible, however, to eliminate some materials that did not effectively control the crawlers. As an example, malathion gave a very poor kill in the fall spray, and therefore that material was not used during the winter or spring.

Of the compounds used, parathion and Diazinon gave the best control, regardless of the timing of treatments. Trithion, Phostex, and Sevin, although reducing fruit damage below that of the checks, did not compare with either parathion or Diazinon.

None of the sprays caused any serious phytotoxic effects to the trees, although the fall sprays in combination with oil caused a little foliage damage. These results are preliminary and additional plot work is planned for the 1959 season. It may be possible that treatments more closely timed to the first or second generation will give better control. With present knowledge, a petal fall spray of either parathion or Diazinon seems the most feasible method of control.

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PINE ROOTS

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were removed from the water baths and the seedlings carefully washed from the sand. The new roots, which had just started to harden—but could be recognized as new roots—were counted and those 0.5″ and longer were measured. The air temperature in the greenhouse did not fall below 68°F at night and with but few exceptions did not exceed 95°F during the day. Thus the seedling roots were exposed to a constant temperature, an abundant supply of moisture and nutrients, and the top was exposed to a varying air temperature and a changing photoperiod.

The 1956–57 series was handled in the same fashion except that sponge-rock was substituted for the sand.

Findings

Seedlings from Zone V seed grown at the Mt. Shasta Nursery behaved differently than seedlings from Zone III seed grown at Placerville, although both groups showed a pronounced seasonal periodicity in root elongation and root initiation when transferred at monthly intervals to the greenhouse. Root elongation on seedlings from both zones occurred from September through May and was absent, or of a limited nature, from June through August with the peak occurring on Zone V seedlings in May and on Zone III seedlings two months earlier in March. Some root initiation was evident from September to June but was prominent on Zone V seedlings only during April and May and on Zone III seedlings only from December to May.

The seasonal ability to initiate roots might on occasion be an important factor in determining the relative ability of fall and spring planted seedlings to survive. In the process of lifting, storing, shipping, and planting a number of the short laterals are destroyed. If it is a spring lifted seedling it will readily regenerate a number of new laterals some of which will then rapidly elongate; if lifted in the fall few if any new laterals will be formed.

Although Zones III and V stock showed significantly different behavior the difference must be interpreted with caution. Obviously, different lots of two year old ponderosa pine seedlings can be expected to perform differently when field planted. However, whether or not the difference in these two particular lots was due to the seed zone, the climate in which they were grown, the way they were lifted, the kind of temporary storage, the shipping conditions, or some unrecognized factor can not be determined from available data.

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along with a conductance value of 4.8 millimhos—just over the saline threshold. Iron sulfate clearly increased yields but production was low regardless of iron treatment. Whether the poor performance was due to high sodium, to high salinity, or to both is not known at present.

Soils where rice fails are calcareous and characterized by a high pH, along with a relatively low salinity. Rice plants die of iron deficiency as seedlings because of low iron-supplying power of the soil, which seems to be associated with high pH under flooded conditions.

The use of ferric sulfate appears an effective means of raising rice production to economic levels on high pH, nonsaline soils which occur as localized spots in many fields in Glenn and Colusa counties. Where high salinity is encountered ferric sulfate treatments may not be expected to be effective until the soluble salt content of the soil is reduced by leaching.

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