Response of rice to preplant soil application of zinc sulphate, equivalent to supplying 8 pounds of zinc per acre. Note that in the untreated area, the seedling plants failed to survive.

Zinc Deficiency

D. S. MIKKELSON

The so-called "alkali disease" syndrome observed widely in California rice, causing chlorosis in seedling plants and often effecting a partial to complete loss of stand, has been identified as zinc deficiency. This problem is extensive in both the Sacramento and San Joaquin valleys. In some areas, entire fields are affected; in others, the problem occurs in irregular patterns, depending particularly upon soil conditions.

Symptoms of zinc deficiency

Symptoms of zinc deficiency appear in water-sown rice as soon as the first true leaves are formed. The chlorosis, which begins at the base of new leaves, spreads quickly to the entire leaf which takes on a pale yellowish-green color, frequently referred to as "bronzing." The severity of the chlorosis increases with time and eventually dark irregular necrotic spots develop in the leaves, which become structurally weak and float on the water. Affected plants usually die within 4 to 6 weeks of planting, and seedlings usually disintegrate in the water. Rice production is sometimes a complete failure in affected areas, though scattered plants may occasionally survive and mature several weeks later than normal.

Zinc deficient soils

Some California soils have a very low level of plant-available zinc, and consequently do not supply enough to meet the needs of rice seedlings. This deficiency frequently occurs where the surface layer of soil has been removed during leveling operations. Zinc deficiency in water-sown rice is usually found in soils with a pH greater than 7.0, on soils containing an exchangeable sodium content greater than 15 percent, or on soils formed from calcareous materials or containing free calcium carbonate. In many areas these same soils may be high in soluble salts, though that does not appear to affect the incidence of zinc deficiency.

A number of other soil and environmental factors are associated with zinc deficiency in rice. A frequent observation is that zinc deficiency is more severe when soils are flooded rather than surface irrigated, and also when crop residues are actively undergoing decomposition. Cool soil temperatures during the early growing season accentuate zinc deficiency problems. Cool soil and water restrict root development in rice, reducing development of the roots, the feeding zone, and the ability for nutrient accumulation. Water temperatures below 65-70°F greatly restrict zinc uptake in rice. Irrigation water that is high in pH and in bicarbonates formed from dissolved carbon dioxide greatly interferes with zinc uptake. In some instances, selecting sources of irrigation water with better characteristics will alleviate zinc deficiency in water-sown rice.

Diagnosis in rice soils

Soil analysis has proven to be an effective means of identifying soils where zinc deficiency is likely to be a nutritional problem. Plant-available zinc can be measured in soils collected during seedbed preparation. Representative field dry samples are crushed and sieved to a 2-mm particle size prior to extraction with a DTPA extracting solution. This is made by dissolving 2.0 grams of DTPA [[(carboxymethyl) imino]bis(ethyleneitrilo)] tetra-acetic acid, 15.0 grams of triethanolamine, and 1.1 grams of anhydrous calcium chloride in high-purity distilled water and diluting to one liter. The pH of the solution should be adjusted exactly to pH 7.3 with hydrochloric acid. Ten grams of air-dried 2-mm soil are extracted with 20 ml of the DTPA extracting reagent in vials with polyethylene caps. The extraction requires 2 hours on a rapid-action reciprocating shaker. After filtering, the zinc concentration in the filtrate is determined by atomic absorption spectrophotometry. Parts-per-million (ppm) zinc in the soil is equal to ppm Zn in the filtrate times two.

In soil samples collected from 50 fields where zinc fertilization experiments have been conducted, a good correlation has been found bet-

TABLE 1. EFFECT OF ZINC SOURCES AND RATES ON RICE YIELDS

Source	Zn rate	Yield of rough rice: Willows cl	Yield of rough rice: Plaza si cl	Yield of rough rice: Mormon cl	Mean Zn content
	lb/A		lb/A		Seedlings* ppm
Control	0	1130 d	0	1984 d	13.5
$ZnSO_4$	2	3475 b	3420 b	5815 c	21.0
$ZnSO_4$	4	4085 a	3650 ab	7515 b	23.0
$ZnSO_4$	8	3790 ab	4130 a	8220 a	25.0
ZnO	2	2970 c	2370 c	6425 c	19.0
ZnO	4	3325 b	2725 bc	7915 ab	22.0
ZnO	8	3785 ab	2950 b	7645 b	25.0
Zn LS	2	3710 ab	3195 b	7990 ab	43.0
Zn LS	4	4060 a	3920 a	8680 a	47.0
Zn LS	8	4160 a	4175 a	--	51.0
Zn EDTA	2	2970 c	2230 c	--	15.0
Zn EDTA	4	3325 b	2950 bc	-	17.0
Zn EDTA	8	3795 ab	3200 b	--	20.0

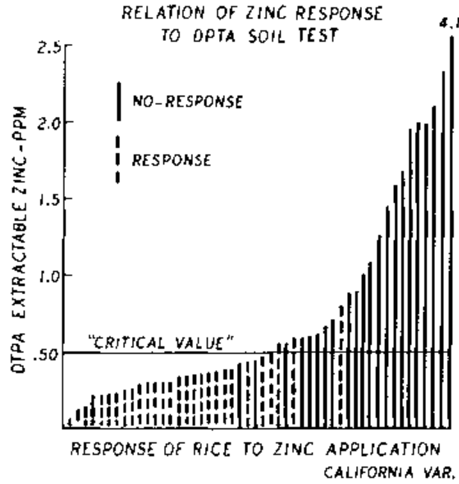
*Seedlings -- 30 days old.
LS = Zn lignosulfonate
EDTA = Ethylenediaminetetra-acetic acid

Mean values with the same letter are not statistically different at .05 probability level.

in California Rice

D. M. BRANDON

ween soil test values obtained by the DTPA extraction procedure and crop yield response. Yield responses are usually obtained when the zinc level in the soil is below 0.5 ppm (graph 1).



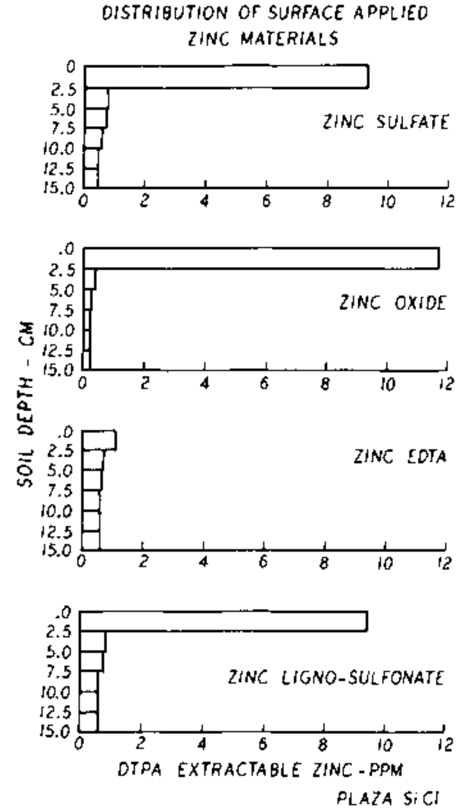
Correction of zinc deficiency

In table 1 is presented the effects of different sources and rates of zinc on the yield of rice, and average zinc content of seedling rice plants 30 days old. Among the inorganic zinc sources the sulfate, chloride, and nitrate forms have been found equally effective in correcting zinc deficiency, and their effect is characterized in table 1 by the zinc sulfate responses. Zinc oxide has been slightly less effective than zinc sulfate, but per unit of applied zinc, its cost is generally lower, offsetting any economic disadvantage. Two chelate materials, ZnEDTA (a synthetic organic chelate) and ligsulfonate (an organic chelate prepared from fermented spent wood pulp liquor) have given widely differing responses. The ZnEDTA has given consistently poorer plant growth and yield responses than the Zn lignosulfonate. Zinc uptake by seedling plants has been significantly higher with the zinc lignosulfonate than with other zinc sources tested.

The effect of rate of zinc application on rice yields (tables 1 and 2) shows that rice yields are usually increased up to a level of 8 pounds actual zinc per acre with the inorganic zinc sources. In these and other field experiments, only in unusual cases were zinc application rates greater than 8 pounds actual zinc per acre required to correct the deficiency.

Surface placement

Table 2 indicates that the method of application or placement effect of the applied zinc, and its movement in soil in respect to the roots of seedling rice are important in rice crop response. Zinc applied to the soil surface, prior to flooding, gave significantly better seedling growth, zinc uptake, and ultimately higher grain yields than did incorporation of zinc materials from 2 to 4 inches deep. For zinc to be effective for seedling water-sown rice, it must be positionally available to the roots of the seedling rice, which are initially active at only the soil surface. Zinc fertilizers which are beneath the effective rooting zone, of too large particle size, or physically removed from the rice root, are not effective. Zinc movement is extremely restricted in soils and must be positionally located to favor zinc uptake. Graph 2 shows the relative movement of four zinc sources applied to the surface of a rice soil and subsequently moved by the application of 12 acre-inches of irrigation water. Zinc sources which remain in the surface 1 inch of soil perform significantly better than those which move beyond the depth of seedling root development.



Coating rice seed with zinc sulfate or zinc oxide is another satisfactory means of correcting zinc deficiency in water-sown rice. Either material coated on seed to provide 2 pounds actual zinc for each 100 pounds of seed has proven effective in correcting zinc deficiency in water-sown rice.

Both soil test results and plant response indicate that zinc fertilizers have a significant residual effect that persists for several years. When soil test values increase to levels above 0.6 ppm Zn, responses to additional zinc have not usually given a significant yield increase. Zinc fertilizers in rice have shown residual values over a period of 2 to 3 years. The residual value of zinc fertilizer varies with soil type and soil chemical characteristics. Soil tests should be used to determine whether adequate amounts are available for each crop.

TABLE 2. EFFECT OF ZINC SOURCES AND METHOD OF APPLICATION ON RICE YIELDS

Source	Zn rate	Method of application		Source[1/] Mean
		Surface	Incorporated	
	lb/A	lb/A	lb/A	lb/A
Control	0	2190	2190	2190 c
$ZnSO_4$	2	6465	5925	6195 b
$ZnSO_4$	4	7570	6700	7135 a
$ZnSO_4$	8	7100	5165	6634 a
$ZnSO_4$	16	6705	6180	6442 b
ZnO	2	6915	6145	6481 b
ZnO	8	7225	6540	6884 a
	Methods mean	6295 a	5692 b	

[1/] Mean values with the same letter are not different statistically at .05 probability level.

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