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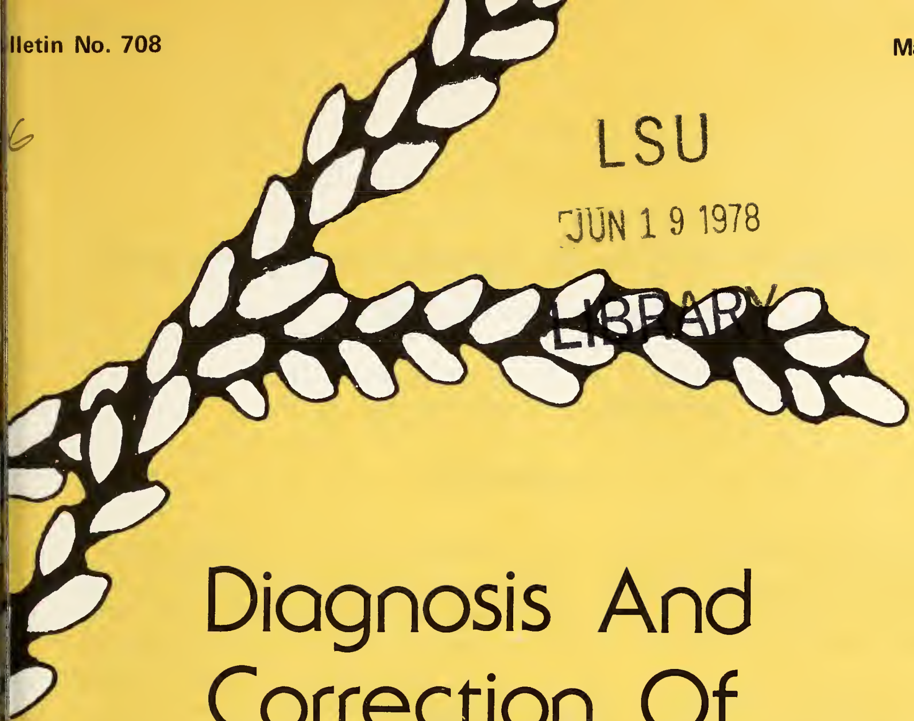

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Introduction

Investigations of different aspects of the zinc (Zn) nutrition of the rice plant have been in progress for 11 years in Louisiana. Research conducted under field conditions indicates that Zn deficiency in rice grown on soils of the coastal prairies in the southwestern area of the state is associated with certain soil and climatic conditions.

Soil reaction, or the pH value of the soil, apparently has the most important influence on Zn availability. It has been noted that a one-unit rise in soil reaction, from pH 5.3 to 6.3, drastically reduced the solubility and uptake of Zn by the rice plant.

Soil-test summaries indicate that approximately 15 per cent of the surface soils in the rice area in their natural condition are neutral to alkaline in reaction. The pH values of other soils have been increased by applications of limestone or by repeated use of irrigation water from wells or other sources that contain appreciable amounts of Na, Ca, and Mg salts.

Since Zn is less available as the pH of the soil approaches neutrality, soils used for the production of rice should be kept moderately acid. In most soils, Zn should be readily available at a pH of about 5.5.

An investigation was initiated in 1968 and continued through 1974 to determine the effects of five rates of Zn on the yield of rice (*Oryza sativa* L.) and on the chemical composition of the soil and the leaves of rice plants grown on Crowley silt loam (Typic Albaqualf) with an initial pH greater than 7.5. Due to an infestation of red rice, the experimental area was fallow-plowed in 1972, and yield data were not obtained for that year.

In 1971 the experiment was included as a contribution to Project S-80, "Diagnosis and Correction of Zinc Problems in Crop Production." Only the results obtained in 1971, 1973, and 1974 are included in this publication.

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Experimental Procedure

Several years prior to the initiation of the investigation, the experimental site was water leveled, and a maximum cut of 6 inches was made to facilitate drainage and the application of flood water. Limestone was also added to create an alkaline pH to increase the response to Zn.

The experimental design was a randomized block with four replications of each of five rates of Zn. The plot size was 7 feet x 50 feet.

The Zn was applied at 0, 3, 6, 12, and 24 pounds per acre. The source of Zn was $ZnSO_4 \cdot H_2O$, 36 percent Zn. Equivalent amounts of S as Na_2SO_4 were added to each plot to insure that all plots received the same amounts of S. Zn was broadcast on the soil surface in an aqueous solution immediately before planting. The Zn treatments were applied in 1968, 1969, and 1971.

Each plot received a uniform annual application of 120 pounds of N, 22 pounds of P, and 42 pounds of K per acre; the fertilizer sources were urea, 46 percent N; concentrated superphosphate, 20.2 percent P; and muriate of potash, 50 percent K. The fertilizer was applied with a drill at planting.

Saturn rice was planted in 1971 and Vista was planted in 1973 and 1974. The rice cultivars were planted with a drill at a seeding rate of 90 pounds per acre. Each plot consisted of 12 drill rows spaced 7 inches apart.

Soil samples were collected annually from each plot prior to the application of the plant nutrient elements. The soil samples were air-dried at room temperature, ground to pass a 2-mm stainless steel sieve, and stored in 16-ounce plastic bags. The soil samples were analyzed by state soil testing laboratories in Florida, Virginia, and Kentucky.

Tissue samples were collected annually from the plants on each of the plots. The tissue samples consisted of 100 mature leaves taken when the rice panicle was approximately 2 mm long. The leaves were rinsed in distilled water, placed in cotton bags, and dried in a forced draft oven at 67°C for 12 hours. The dried leaves were ground in a stainless steel Wiley mill to pass a 20-mesh sieve and stored in 8-ounce plastic bags. The plant tissue samples were analyzed by laboratories at the University of Georgia and Texas A&M University.

The yield, plant tissue, and soil chemical analyses data were evaluated using analyses of variance (randomized block design) and correlation analyses.

Results and Discussion

Treatment means for the rice yield and plant and soil chemical analyses by year and for all years combined are presented in Tables 1 through 4. The analyses of variance are presented in Tables 5 and 6. The data show that a highly significant response in yield was obtained from the application of

Table 1.—Treatment means for rice yield and plant and soil chemical analyses (1971)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	2322.30	3244.25	3133.50	3340.25	3691.00
PLANT ANALYSIS					
Ga. P, %	0.16	0.17	0.17	0.18	0.17
Ga. K, %	1.69	1.68	1.48	1.63	1.39
Ga. Ca, %	0.14	0.13	0.12	0.12	0.11
Ga. Mg, %	0.15	0.14	0.13	0.13	0.11
Ga. Mn, ppm	275.50	259.50	223.00	213.75	199.25
Ga. Fe, ppm	51.50	47.00	43.25	44.25	44.25
Ga. B, ppm	4.00	6.00	5.25	6.00	5.50
Ga. Cu, ppm	7.75	8.00	9.00	8.25	7.75
Ga. Zn, ppm	14.25	15.50	17.00	16.00	23.25
Ga. Al, ppm	26.50	26.00	23.50	21.25	24.00
Ga. Mo, ppm	2.53	2.63	2.43	2.40	2.68
Ga. Sr, ppm	8.50	7.25	6.50	6.75	7.75
Ga. Ba, ppm	39.00	36.50	32.50	33.00	28.00
Ga. Na, ppm	872.00	689.25	655.00	543.50	712.75
Tex. Zn, ppm	9.63	12.75	11.00	12.63	11.75
SOIL ANALYSIS					
Fla. Zn[1], ppm	1.93	2.25	2.85	3.60	6.05
Fla. Zn[2], ppm	1.50	1.85	2.45	2.95	5.13
Fla. Zn[3], ppm	0.73	0.90	1.13	1.43	2.28
Va. pH	7.73	7.70	7.63	7.65	7.73
Va. O.M., %	0.98	1.00	0.90	0.70	0.78
Va. Ca, lbs./acre	2344.00	2344.00	2344.00	2344.00	2344.00
Va. Mg, lbs./acre	239.00	239.00	239.00	239.00	239.00
Va. P, lbs./acre	6.00	6.50	5.75	5.75	5.00
Va. K, lbs./acre	76.50	81.50	76.50	74.00	79.00
Ky. pH	7.50	7.15	7.08	7.33	7.33
Ky. Ca, lbs./acre	——	——	——	——	——
Ky. Mg, lbs./acre	——	——	——	——	——
Ky. P, lbs./acre	4.30	4.00	4.00	4.00	4.00
Ky. K, lbs./acre	105.30	110.00	110.00	106.00	82.30

[1]0.1 *N* HCl [2]0.05 *N* HCl in 0.025 *N* H_2SO_4 [3]DTPA-TEA

Table 2.—Treatment means for rice yield and plant and soil chemical analyses (1973)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	3784.50	3880.50	4016.50	3875.75	3904.25
PLANT ANALYSIS					
Ga. P, %	0.20	0.19	0.19	0.17	0.19
Ga. K, %	1.90	1.57	1.69	1.72	1.90
Ga. Ca, %	0.16	0.13	0.13	0.13	0.14
Ga. Mg, %	0.18	0.14	0.14	0.11	0.14
Ga. Mn, ppm	150.25	128.25	140.00	121.25	133.00
Ga. Fe, ppm	85.50	81.75	80.25	75.75	137.00
Ga. B, ppm	9.25	10.00	10.00	8.75	9.75
Ga. Cu, ppm	9.75	6.00	6.00	4.50	8.75
Ga. Zn, ppm	19.00	20.75	25.25	20.75	27.50
Ga. Al, ppm	86.50	81.00	65.50	63.25	75.00
Ga. Mo, ppm	1.03	1.58	1.43	1.33	1.38
Ga. Sr, ppm	11.50	8.50	7.75	9.75	9.25
Ga. Ba, ppm	6.50	4.25	4.25	4.00	4.50
Ga. Na, ppm	342.00	289.50	339.50	268.50	338.00
Tex. Zn, ppm	19.03	17.78	20.90	27.25	28.28
SOIL ANALYSIS					
Fla. Zn[1], ppm	2.23	2.70	3.13	4.30	6.85
Fla. Zn[2], ppm	1.88	2.13	2.55	3.45	5.38
Fla. Zn[3], ppm	0.90	0.95	1.00	1.55	2.55
Va. pH	7.28	7.45	7.25	7.30	7.28
Va. O.M., %	0.90	1.00	0.90	0.70	0.78
Va. Ca, lbs./acre	2167.30	2251.50	2128.50	2089.00	2310.00
Va. Mg, lbs./acre	240.00	240.00	240.00	240.00	240.00
Va. P, lbs./acre	4.30	5.80	8.50	6.30	4.30
Va. K, lbs./acre	52.00	48.50	54.50	51.50	50.00
Ky. pH	7.60	7.30	7.40	7.30	7.50
Ky. Ca, lbs./acre	1840.00	1930.00	1847.50	1862.50	1892.50
Ky. Mg, lbs./acre	596.30	683.50	631.00	617.30	665.00
Ky. P, lbs./acre	3.00	3.50	3.80	3.80	3.00
Ky. K, lbs./acre	90.00	98.80	99.80	100.00	100.80

[1]0.1 N HCl [2]0.05 N HCl in 0.025 N H_2SO_4 [3]DTPA-TEA

Table 3.—Treatment means for rice yield and plant and soil chemical analyses (1974)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	4754.50	4354.50	4892.75	5128.50	4977.75
PLANT ANALYSIS					
Ga. P, %	0.17	0.15	0.16	0.17	0.16
Ga. K, %	2.09	1.96	1.90	2.08	2.02
Ga. Ca, %	0.15	0.13	0.13	0.15	0.13
Ga. Mg, %	0.15	0.13	0.13	0.14	0.12
Ga. Mn, ppm	384.50	335.25	333.50	383.75	339.25
Ga. Fe, ppm	44.50	39.25	40.75	45.75	44.25
Ga. B, ppm	4.00	3.75	3.75	4.00	4.00
Ga. Cu, ppm	2.50	2.25	2.00	2.75	2.25
Ga. Zn, ppm	13.50	13.75	14.25	16.25	16.75
Ga. Al, ppm	13.50	12.75	13.25	14.75	12.00
Ga. Mo, ppm	2.20	2.10	1.95	2.13	2.18
Ga. Sr, ppm	7.25	7.00	6.50	6.75	6.50
Ga. Ba, ppm	10.25	8.25	7.50	9.25	7.50
Ga. Na, ppm	123.25	131.75	99.25	98.25	140.00
Tex. Zn, ppm	17.00	17.25	19.88	20.63	18.25
SOIL ANALYSIS					
Fla. Zn[1], ppm	1.27	2.41	1.48	2.26	1.93
Fla. Zn[2], ppm	0.84	1.91	1.00	1.97	1.57
Fla. Zn[3], ppm	0.41	1.05	0.52	1.03	0.88
Va. pH	7.43	7.63	7.55	7.50	7.55
Va. O.M., %	0.73	0.70	0.93	1.03	1.08
Va. Ca, lbs./acre	2358.00	2338.30	2328.50	2358.00	2333.50
Va. Mg, lbs./acre	239.00	239.00	239.00	239.00	239.00
Va. P, lbs./acre	3.50	3.00	4.30	3.80	2.80
Va. K, lbs./acre	56.00	50.00	38.00	50.50	38.50
Ky. pH	7.80	7.80	7.70	7.60	7.60
Ky. Ca, lbs./acre	1817.50	1820.00	1805.00	1792.50	1822.50
Ky. Mg, lbs./acre	513.00	537.00	518.30	507.00	568.50
Ky. P, lbs./acre	5.50	6.30	7.30	6.80	6.50
Ky. K, lbs./acre	102.80	99.00	100.30	102.50	100.00

[1]0.1 *N* HCl [2]0.05 *N* HCl in 0.025 *N* H_2SO_4 [3]DTPA-TEA

Table 4.—Treatment means for rice yield and plant and soil chemical analyses (three year averages)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	3620.42	3826.42	4014.25	4114.83	4191.00
PLANT ANALYSIS					
Ga. P, %	0.18	0.17	0.18	0.17	0.17
Ga. K, %	1.89	1.73	1.69	1.81	1.77
Ga. Ca, %	0.15	0.13	0.13	0.13	0.12
Ga. Mg, %	0.16	0.14	0.13	0.12	0.12
Ga. Mn, ppm	270.08	241.00	232.17	239.58	223.83
Ge. Fe, ppm	60.50	56.00	54.75	55.25	75.17
Ga. B, ppm	5.75	6.58	6.33	6.25	6.42
Ga. Cu, ppm	6.67	5.42	5.67	5.17	6.25
Ga. Zn, ppm	15.58	16.67	18.83	17.67	22.50
Ga. Al, ppm	42.17	39.92	34.08	33.08	37.00
Ga. Mo, ppm	1.92	2.10	1.93	1.95	2.08
Ga. Sr, ppm	9.08	7.58	6.92	7.75	7.83
Ga. Ba, ppm	18.58	16.33	14.75	15.42	13.33
Ga. Na, ppm	445.75	370.17	364.58	303.42	396.92
Tex. Zn, ppm	15.22	15.93	17.26	20.17	19.43
SOIL ANALYSIS					
Fla. Zn[1], ppm	1.81	2.45	2.49	3.39	4.94
Fla. Zn[2], ppm	1.41	1.96	2.00	2.79	4.03
Fla. Zn[3], ppm	0.68	0.97	088	1.34	1.90
Va. pH	7.48	7.59	7.48	7.48	7.52
Va. O.M., %	0.87	0.90	0.91	0.81	0.88
Va. Ca, lbs./acre	2289.75	2311.25	2267.00	2263.67	2329.17
Va. Mg, lbs./acre	239.33	239.33	239.33	239.33	239.33
Va. P, lbs./acre	4.58	5.08	6.17	5.25	4.00
Va. K, lbs./acre	61.50	60.00	56.33	58.67	55.83
Ky. pH	7.62	7.42	7.40	7.42	7.45
Ky. Ca, lbs./acre	1828.75	1875.00	1826.25	1827.50	1857.50
Ky. Mg, lbs./acre	554.63	610.25	574.63	562.13	616.75
Ky. P, lbs./acre	4.25	4.58	5.00	4.83	4.50
Ky. K, lbs./acre	99.33	102.58	103.33	102.83	94.33

[1]0.1 *N* HCl   [2]0.05 *N* HCl in 0.025 *N* H_2SO_4 [3]DTPA-TEA

Zn. When the data for the three years were combined, it was found that yields were increased at all levels of applied Zn. A per-acre increase of 206, 394, 494, and 571 pounds of rough rice resulted from the application of 3, 6, 12, and 24 pounds of Zn per acre, respectively.

As expected, levels of plant tissue Zn generally increased as the level of applied Zn was increased. The Texas and Georgia values for plant Zn were in rather close agreement ($r = 0.336$, $P < 0.01$, Table 7). The data in Table 4 indicate that a Zn concentration of approximately 15 ppm in rice leaf tissue is below the levels where highest yields were obtained. The means presented in Table 4 indicate that the Mn concentration in the leaves decreased as the rate of applied Zn was increased. A highly significant negative correlation ($r = -0.482$) was obtained between the concentration of Zn and Mn in the leaf tissue (Table 7).

The data in Table 4 show that the application of the different rates of Zn resulted in increases in the level of soil-test Zn determined by the three methods of extraction. Higher quantities of Zn were extracted with 0.1 *N* HCl than with 0.05 *N* HCl in 0.025 *N* H_2SO_4 or with DTPA-TEA. The data show that approximately 1.8 ppm of Zn extracted with 0.1 *N* HCl was a marginal level of Zn in Crowley silt loam for the economical production of rice. Corresponding values of 1.4 ppm and 0.7 ppm of Zn extracted with 0.05 *N* HCl in 0.025 *N* H_2SO_4, and with DTPA-TEA, respectively, were also considered to be marginal levels for rice. The data in Table 8 show that highly significant positive correlations were obtained for the three methods used for extracting soil Zn. Highly significant positive correlation coefficients were also obtained between the yield of rice and the three methods of extracting Zn from the soil.

Deficiency symptoms attributed to low levels of Zn in the tissue were observed visually on rice plants growing on plots that did not receive an application of Zn. In early stages of growth the symptoms appeared as a sudden blighting of the oldest leaves of the seedling. The lesions were surrounded by chlorotic areas which became white. The lesions and chlorotic areas extended from the sheath up the midrib of the oldest true leaf, parallel to the leaf veins. As the disorder developed, the base of the leaf blade and mid-vein became bleached with brown flecks, spots, and irregular linear blotches. The affected leaves rapidly became blighted and the seedlings appeared to be dead. However, when the blighted outer leaves were removed, the youngest leaf remained green. Cool, overcast weather contributed to the symptoms, and extended periods of adverse weather together with a high infestation of rice water weevils increased the intensity of the visually observed deficiency symptoms.

Zinc deficiency symptoms often are not expressed until the permanent flood is applied to a field. Initially the lower leaves of affected plants become limp and float on the surface of the flood water. These leaves

Table 5.—Analysis of variance for rice yield and plant analyses by the Georgia and Texas laboratories (three years combined)[1]

Source of variation	d.f.	Yield	Georgia							
			P	K	Ca	Mg	Mn	Fe	B	Cu
Year	2	14089955.7**	0.002962**	0.961665**	0.001552	0.000602	244305.717**	15138.82**	172.2167**	188.6167**
Rep/year	9	203322.5	0.000512*	0.077559**	0.001434*	0.001339	978.789	211.79	2.8556	2.7889
Treatment	4	639659.6**	0.000054	0.070968*	0.001064	0.002848**	3660.042*	887.54	1.1833	4.5417
Treatment x year	8	378695.8*	0.000312	0.052567*	0.000233	0.000443	1871.467	881.13	1.3833	7.8667
Error	36	160529.8	0.000225	0.022094	0.000590	0.000719	1018.525	440.62	2.7167	5.1917

Table 5.—(Continued)

Source of variation	d.f.	Yield	Georgia						Texas
			Zn	Al	Mo	Sr	Ba	Na	Zn
Year	2	14089955.7**	316.850**	21140.00**	7.2195**	36.017**	4997.32**	1714086.67**	630.55**
Rep/year	9	203322.5	25.728	129.03	0.1428	6.078	52.97*	13376.16	18.23
Treatment	4	639659.6**	85.083*	176.21	0.0882	7.417	45.89*	32205.42*	55.56*
Treatment x year	8	378695.8*	12.183	119.71	0.0855	1.829	17.13	15066.60	27.04
Error	36	160529.8	22.561	98.60	0.1858	4.314	14.97	9953.20	16.74

[1]Mean squares are reported. *Denotes a significant difference at 5%. **Denotes a significant difference at 1%.

rapidly turn yellow-orange and develop small brown flecks. In the more severely affected areas of fields or in deep water, seedlings begin to disappear below the surface of the flood water, the rice stand thins, and areas of open water appear. Plants that do not die under deficiency conditions are often stunted and have brown flecks on the leaf blades. These flecks expand into irregular, linear, purple-brown blotches on the older leaves. If the affected plants have responded to an application of N fertilizer before the ''bronzing'' symptoms are expressed, a distinctive chlorotic area which rapidly becomes white is often observed in the mid-leaf area and around the brown blotches. The leaf blade or tip of the blade may become bronze in color due to the formation and coalescence of many small purple-brown flecks. From a distance the plants in a field take on a bronze to gold color. Often plants in the affected field exhibit typical N deficiency symptoms as well as those typical of ''bronzing.'' Zinc deficiency appears to interfere with the normal utilization of N.

Plants can exhibit Zn deficiency symptoms at any stage of growth. If plants become deficient at heading, the leaves and glumes will show the typical chlorosis, brown flecking, and spotting. When Zn deficiency becomes severe at heading, the florets are affected. A condition similar to straight-head may occur where the panicles of affected plants remain upright as fertilization fails to take place or kernel development is aborted.

The data presented indicate that the concentration of Fe in the plant tissue was relatively low at all levels of applied Zn. Preliminary investigations have indicated that Fe deficiency can be expected when the level of Fe in rice leaves at the tillering stage of plant development falls below 70 ppm. The Zn treatments had no significant influence on the level of Fe in the rice leaves. The low levels of Fe found in the tissue may have been due to the low solubility of Fe in the Crowley silt loam at pH values of 7.5.

The B contents of the rice-leaf tissue at all of the levels of applied Zn varied from 5.8 ppm to 6.6 ppm (Table 4). These values for B are higher than the critically low value of 3.5 ppm that has been established for rice plants.

The data also indicate that the Cu content of the rice leaves at all of the levels of applied Zn was relatively low. Copper deficiency in rice may be expected when the concentration of Cu in rice leaves is below 6 ppm. A significant response to application of Cu was obtained on a Crowley silt loam at another location prior to the initiation of the current investigation.

Many other correlations among the variables measured proved to be significant, indicating that additional research is needed on the role of the macro- and micronutrient elements in the nutrition of rice plants.

Table 6.—Analysis of variance for rice yield and soil analyses by the Florida, Virginia and Kentucky laboratories (three years combined)[1]

Source of variation	d.f.	Yield	Florida			Virginia				
			0.1 *N* HCl	0.05 *N* HCl in 0.025 *N* NH_2SO_4	DTPA-TEA Zn	pH	Organic matter	Ca	P	K
Year	2	14089955.7**	1522.85**	903.71**	275.254**	0.7102**	0.0062	158880.42**	36.82**	5544.47**
Rep/year	9	203322.5	3.65	4.65*	3.138**	0.0144	0.0202	24683.86	1.57	76.84
Treatment	4	639659.6**	59.63**	58.90*	17.691**	0.0296	0.0186	9553.88**	7.81*	69.23
Treatment x year	8	378695.8*	30.42**	32.05*	10.088**	0.0131	0.1103**	11949.56	3.55	119.13
Error	36	160529.8	3.36	1.70	0.618	0.0170	0.0175	6528.41	3.27	49.57

Table 6.—(Continued)

Source of variation	d.f.	Yield	Kentucky		
			pH	P	K
Year	2	14089955.7**	0.8645**	51.62**	120.22
Rep/year	9	203322.5	0.0261	0.43	194.73
Treatment	4	639659.6**	0.0960**	1.03	171.60
Treatment x year	8	378695.8*	0.0501	0.64	230.24
Error	36	160529.8	0.0299	1.21	217.99

Source of variation	d.f.	Kentucky	
		Ca	Mg
Year	1	39690.00**	120670.23**
Rep/year	6	31911.67**	8016.16**
Treatment	4	3916.25	6380.79**
Treatment x year	4	2183.75	1118.79
Error	24	4686.67	1426.05

[1]Mean squares are reported. *Denotes a significant difference at 5%. **Denotes a significant difference at 1%.

Table 7.—Simple correlation coefficients (r) for rice yield and plant and soil analyses (all years combined)

		Plant analyses														
		Georgia														Texas
	Yield	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo	Sr	Ba	Na	Zn
Yield	1.000	-0.089	0.546**	0.117	-0.110	0.406**	-0.075	-0.151	-0.571**	-0.006	-0.213	-0.169	-0.193	-0.638**	-0.824**	0.446**
PLANT ANALYSES																
Ga. P	-0.089	1.000	0.115	0.328*	0.569**	-0.359**	0.530**	0.615**	0.503**	0.528**	0.654**	-0.199	0.301*	-0.135	0.073	0.245
Ga. K	0.546**	0.115	1.000	0.612**	0.378**	0.566**	0.059	-0.158	-0.354**	-0.062	-0.078	-0.117	0.132	-0.325*	-0.540**	0.320*
Ga. Ca	0.117	0.328*	0.612**	1.000	0.680**	0.242	0.198	0.008	0.049	-0.046	0.280*	-0.176	0.507**	-0.073	-0.108	0.110
Ga. Mg	-0.110	0.569**	0.378**	0.680**	1.000	0.134	0.212	0.124	0.354**	0.041	0.375**	-0.253*	0.417**	0.014	0.092	-0.029
Ga. Mn	0.407**	-0.359**	0.566**	0.241	0.134	1.000	-0.537**	-0.740**	-0.495**	-0.482**	-0.737**	0.449**	-0.331**	0.143	-0.276*	-0.224
Ga. Fe	-0.075	0.530**	0.059	0.198	0.212	-0.537**	1.000	0.673**	0.426**	0.556**	0.743**	-0.446**	0.324*	-0.349**	-0.047	0.463**
Ga. B	-0.150	0.615**	-0.158	0.008	0.124	-0.740**	0.673**	1.000	0.410**	0.582**	0.813**	-0.417**	0.183	-0.277*	0.017	0.384**
Ga. Cu	-0.571**	0.503**	-0.354**	0.049	0.354**	-0.495**	0.426**	0.410**	1.000	0.307*	0.467**	-0.130	0.343**	0.418**	0.628**	-0.186
Ga. Zn	-0.006	0.528**	-0.062	-0.046	0.041	-0.482**	0.556**	0.582**	0.307*	1.000	0.521**	-0.265*	0.050	-0.171	-0.001	0.336**
Ga. Al	-0.213	0.654**	-0.078	0.280*	0.375**	-0.737**	0.743**	0.813**	0.467**	0.521**	1.000	-0.628**	0.546**	-0.371**	0.029	0.420**
Ga. Mo	-0.169	-0.199	-0.177	-0.176	-0.253*	0.449**	-0.446*	-0.417**	-0.130	-0.265*	-0.628**	1.000	-0.508**	0.601**	0.365**	-0.575**
Ga. Sr	-0.193	0.301*	0.132	0.507**	0.417**	-0.331**	0.324*	0.183	0.343**	0.050	0.546**	-0.508**	1.000	-0.146	0.123	0.183
Ga. Ba	-0.638**	-0.135	-0.325*	-0.073	0.014	0.143	-0.349**	-0.349*	0.418**	-0.171	-0.371**	0.601**	-0.146	1.000	0.776**	-0.676**
Ga. Na	-0.824**	0.073	-0.540**	-0.108	0.092	-0.276*	-0.047	0.017	0.628**	-0.001	0.029	0.365**	0.123	0.776**	1.000	-0.518**
Texas Zn	0.446**	0.245	0.320*	0.110	-0.029	-0.224	0.463**	0.384**	-0.186	0.336**	0.420**	-0.575**	0.183	-0.676**	-0.518**	1.000
SOIL ANALYSES																
Fla. Zn[1]	0.713**	-0.381**	0.587**	0.118	-0.086	0.713**	-0.298*	-0.515**	0.649**	-0.275*	-0.526**	0.112	0.253*	-0.375**	-0.648**	0.164
Fla. Zn[2]	0.691**	-0.372**	0.552**	0.102	-0.106	0.684**	0.290*	-0.502**	-0.616**	-0.257*	-0.509**	0.106	-0.243	-0.355**	-0.618**	0.149
Fla. Zn[3]	0.665**	-0.359**	0.562**	0.132	-0.082	0.678**	-0.291*	-0.499**	-0.598**	-0.268*	-0.503**	0.107	-0.219	-0.336**	-0.599**	0.125
Va. pH	-0.292*	-0.380**	-0.241	-0.197	-0.130	0.358**	-0.555**	-0.537**	0.007	-0.365**	-0.585**	0.579**	-0.269*	0.615**	0.417**	-0.611**
Va. O.M.	0.100	0.106	0.026	0.056	0.213	0.116	-0.019	-0.039	0.145	-0.094	0.001	-0.009	-0.074	-0.017	0.046	-0.072
Va. Ca	-0.022	-0.287*	-0.049	-0.127	-0.005	0.415**	-0.270*	-0.434**	-0.018	-0.283*	-0.500**	0.395**	-0.300*	0.328*	0.123	-0.456**
Va. Mg	-0.052	0.494**	-0.066	0.140	0.145	-0.779**	0.717**	0.818**	0.247	0.524**	0.919**	-0.735**	0.460**	-0.565**	-0.163	0.557**
Va. P	-0.401**	0.352**	-0.332**	-0.069	0.033	-0.368**	0.122	0.427**	0.373**	0.355**	0.342**	0.023	0.048	0.230	0.330**	0.042
Va. K	-0.672**	-0.004	-0.492**	-0.153	-0.012	-0.117	-0.225	-0.100	0.447**	0.027	-0.175	0.503**	-0.097	0.799**	0.780**	-0.544**
Ky. pH	0.403**	-0.147	0.539**	0.200	0.204	0.436**	-0.037	-0.208	-0.500**	-0.152	-0.163	-0.114	0.028	-0.403**	-0.516**	0.171
Ky. Ca	-0.374*	0.207	-0.276	-0.050	0.147	-0.353*	0.372*	0.382*	0.349*	0.259	0.335*	-0.224	0.166	-0.372*	0.392*	0.048
Ky. Mg	-0.684**	0.397*	-0.472**	-0.136	0.090	-0.741**	0.585**	0.729**	0.532**	0.600**	0.682**	-0.414**	0.306	-0.648**	0.783**	0.165
Ky. P	0.545**	-0.220	0.491**	0.110	-0.179	0.757**	-0.407**	-0.515**	-0.558**	-0.305*	-0.533**	0.295*	-0.344**	-0.142	-0.448**	0.104
Ky. K	-0.043	0.796	0.100	0.050	0.011	0.137	-0.082	-0.047	-0.016	0.089	-0.121	0.155	-0.011	0.163	0.033	-0.053

[1]0.1 *N* HCl. [2]0.05 *N* HCl in 0.025 *N* H_2SO_4. [3]DPTA-TEA.

*Denotes a significant difference at 5%.

**Denotes a significant difference at 1 %.

Table 8.—Simple correlation coefficients (r) for rice yield and plant and soil analyses (all years combined)

		Florida			Virginia						Kentucky				
		0.1 *N* HCl	0.025 *N* H_2SO_4	DTPA-TEA											
	Yield	Zn	Zn	Zn	pH	Organic matter	Ca	Mg	P	K	pH	Ca	Mg	P	K
Yield	1.000	0.713**	0.691**	0.665**	-0.292*	0.100	-0.022	-0.052	-0.401**	-0.672**	0.403**	-0.374*	-0.684**	0.545**	-0.043
PLANT ANALYSES															
Ga. P	-0.089	-0.381**	-0.372**	-0.359**	-0.380**	0.106	-0.287*	0.494**	0.352**	-0.004	-0.147	0.207	0.397*	-0.220	0.080
Ga. K	0.546**	0.587**	0.552**	0.562**	-0.241	0.026	-0.049	-0.066	-0.332**	-0.492**	0.539**	-0.276	-0.472**	0.491**	0.100
Ga. Ca	0.117	0.118	0.102	0.132	-0.197	0.056	-0.127	0.140	-0.069	-0.153	0.200	-0.050	-0.136	0.110	0.049
Ga. Mg	-0.110	-0.086	-0.106	-0.082	-0.130	0.213	-0.005	0.145	0.033	-0.012	0.204	0.147	0.090	-0.018	0.011
Ga. Mn	0.407**	0.713**	0.684**	0.678**	0.358**	0.116	0.415**	-0.779**	-0.368**	-0.117	0.436**	-0.353*	-0.741**	0.757**	0.137
Ga. Fe	-0.075	-0.298*	-0.290*	-0.291*	-0.555**	-0.019	-0.270*	-0.717**	0.122	-0.225	-0.037	0.372*	0.585**	-0.407**	-0.082
Ga. B	-0.150	-0.515**	-0.502**	-0.499**	-0.537**	-0.039	-0.434**	0.818**	0.427**	-0.100	-0.208	0.382*	0.729**	-0.515**	-0.047
Ga. Cu	-0.571**	-0.649**	-0.616**	-0.598**	0.007	0.145	-0.018	0.247	0.373**	0.447**	-0.500**	0.349*	0.532**	-0.558**	-0.016
Ga. Zn	-0.006	-0.275*	-0.257*	-0.268*	-0.365**	-0.094	-0.283*	0.524**	0.355**	0.027	-0.152	0.259	0.600**	-0.305*	0.089
Ga. Al	-0.213	-0.526**	-0.509**	-0.503**	-0.585**	0.001	-0.500**	0.919**	0.342**	-0.175	-0.163	0.335*	0.682**	-0.533**	-0.121
Ga. Mo	-0.169	0.112	0.106	0.107	0.579**	-0.009	0.395**	-0.735**	0.023	0.503**	-0.114	-0.224	-0.414**	0.295*	0.155
Ga. Sr	-0.193	-0.253*	-0.243	-0.219	-0.269*	-0.074	-0.300*	0.460**	0.048	-0.097	0.028	0.166	0.306	-0.344**	-0.011
Ga. Ba	-0.638**	-0.375**	-0.355**	-0.336**	0.615**	-0.017	0.328*	-0.565**	0.230	0.799**	-0.403**	-0.372*	-0.648**	-0.142	0.163
Ga. Na	-0.824**	-0.648**	-0.618**	-0.599**	0.417**	0.046	0.123	-0.163	0.330**	0.780**	-0.516**	0.392*	0.783**	-0.448**	0.033
Texas Zn	0.446**	0.164	0.149	0.125	-0.611**	-0.072	-0.456**	0.557**	0.042	-0.544**	0.171	0.048	0.165	0.104	-0.053
SOIL ANALYSES															
Fla. Zn[1]	0.713**	1.000	0.982**	0.973**	0.085	0.046	0.275*	-0.432**	-0.535**	-0.504**	0.579**	-0.292	-0.597**	0.708**	-0.043
Fla. Zn[2]	0.691**	0.982**	1.000	0.992**	0.091	0.052	0.261*	-0.417**	-0.526**	-0.488**	0.523**	-0.305	-0.571**	0.623**	-0.051
Fla. Zn[3]	0.665**	0.973**	0.992**	1.000	0.119	0.058	0.256*	-0.418**	-0.514**	-0.500**	0.527**	-0.316*	-0.565**	0.677**	-0.055
Va. pH	-0.292*	0.085	0.091	0.119	1.000	0.094	0.493**	-0.703**	-0.175	0.486**	-0.023	0.064	-0.230	0.142	0.071
Va. O.M.	0.100	0.046	0.052	0.058	0.094	1.000	0.176	-0.068	-0.040	-0.067	-0.141	0.207	0.083	0.147	0.012
Va. Ca	-0.022	0.275*	0.261*	0.256*	0.493**	0.176	1.000	-0.591**	-0.350**	0.262*	0.145	0.354*	-0.069	0.178	0.218
Va. Mg	-0.052	-0.432**	-0.417**	-0.418**	-0.703**	-0.068	-0.591**	1.000	0.264*	-0.323*	-0.112	0.328*	0.720**	-0.534**	-0.130
Va. P	-0.401*	-0.535**	-0.526**	-0.514**	-0.175	-0.040	-0.350**	0.264*	1.000	0.318*	-0.363**	0.048	0.229	-0.086	0.129
Va. K	-0.672**	-0.504**	-0.488**	-0.500**	0.486**	-0.067	0.262*	-0.323*	0.318*	1.000	-0.412**	0.387*	0.300	-0.355**	0.195
Ky. pH	0.403**	0.579**	0.523**	0.527**	-0.023	-0.141	0.145	-0.112	-0.363**	-0.412**	1.000	0.024	-0.294	0.405**	-0.079
Ky. Ca	-0.374*	-0.292	-0.305	-0.316*	0.064	0.207	0.354*	0.328*	0.048	0.387*	0.024	1.000	0.727**	-0.330*	0.528**
Ky. Mg	-0.684**	-0.597**	-0.571**	-0.565**	-0.230	0.083	-0.069	0.720**	0.229	0.300	-0.294	0.727**	1.000	-0.647**	0.228
Ky. P	0.545**	0.708**	0.673**	0.677**	0.142	0.147	0.178	-0.534**	-0.086	-0.355**	0.405**	-0.330*	-0.647**	1.000	0.057
Ky. K	-0.043	-0.043	-0.051	-0.055	0.071	0.012	0.218	-0.130	0.129	0.195	-0.079	0.528**	0.228	0.057	1.000

[1]0.1 *N* HCl. [2]0.05 *N* HCl in 0.025 *N* H_2SO_4. [3]DPTA-TEA.
*Denotes a significant difference at 5%.
**Denotes a significant difference at 1 %.