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Rotations

Continuous wheat with added N fertilizer gave grain and straw yields equivalent to those obtained in the alfalfa-wheat cropping system. Considering the low yields of alfalfa and the relatively low cost of fertilizer N, the alfalfa-wheat system would have to produce effects over and above the wheat yield effects to be competitive with the continuous wheat system.

In samples taken in 1966, Tanchandrphongs found slightly higher organic matter and greater aggregate stability on the alfalfa-wheat plots than on the continuous wheat plots, but found no differences in soil bulk density. (Tanchandrphongs, Seri. 1967. The effect of different wheat land soil management practices on bulk density, aggregate stability, and organic matter. MS Thesis, Oklahoma State University.) So long as yields can be maintained through use of N fertilizer, and alfalfa has only limited effects beyond supplying N, there is little justification for use of the alfalfa-wheat system.

The N deficiency in the grass-wheat system possibly masked any beneficial effect that grass might have had on wheat production. However, results obtained in the alfalfa-wheat rotation indicate that unless grass has some effect that alfalfa does not have, even with adequate N, a wheat-grass rotation will not outyield adequately fertilized continuous wheat.

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Iron and Zinc Response of Chlorotic Rice Grown on Calcareous Soils[1]

D. G. Westfall, W. B. Anderson, and R.J. Hodges[2]

ABSTRACT

Iron and Zn source and rate experiments were carried out in the field on soils where rice (*Oryza sativa* L.) grain yields had been reduced drastically in previous years by seedling chlorosis.

Soils where seedling chlorosis occurred were higher in pH, HCO_3 and Ca content and lower in Fe and Zn than adjacent soils where normal growth occurred. Iron sulfate, alone or in combination with $ZnSO_4$, was the most effective in correcting seedling chlorosis. A maximum yield increase of over 2,100 kg/ha was obtained with the application of 100 kg/ha of Fe (from $Fe_2(SO_4)_3$). Organic sources of Fe and Zn were less effective in correcting seedling chlorosis and producing yield increases.

Additional index words: Micronutrients.

RICE, *Oryza sativa L.*, grown on calcareous soils in the southern US Rice Belt has been plagued with chlorosis for a number of years. This condition appears during the second to fourth leaf stage of growth causing seedlings to become unthrifty and frequently to die. Flooding the field seems to aggravate the chlorotic symptoms in affected areas; however, plants which survive will regain color, vigor and produce normal panicles. Yield losses of 75% due to reduced plant population and delayed maturity, have occurred in chlorotic fields. The area within a field affected by seedling chlorosis is variable and may range from less than 1 ha to several hectares. This abnormal growth condition has been observed to occur in two different soil situations: (a) where land leveling removed the surface soil containing accumulated micronutrients, and (b) on undisturbed soils with naturally occurring high pH and $CaCO_3$ content.

Chlorosis of rice that is attributed to micronutrient deficiencies in submerged soils is not fully understood. Brown et al. (1) found that Fe-deficiency chlorosis under greenhouse conditions was overcome when calcareous soils were flooded. That finding is contrary to observations in the field by the present authors. Brown et al. (1) attributed Fe-deficiency to antagonistic effects of P and Cu on Fe uptake and utilization.

On nonsaline alkali soils, chlorosis of rice under submerged soil conditions was observed to occur when the first true leaves were formed (3, 5). The plants became more chlorotic with time and eventually developed dark necrotic spots on the leaves. Plants generally died within 4 to 6 weeks, resulting in complete loss of stand. High rates of $Fe_2(SO_4)_3$ (110 to 560 kg/ha) were the most successful treatments in correcting the chlorotic conditions. Soils with higher exchangeable Na required larger amounts of Fe to correct the chlorotic condition (5).

Place and Adams (9) reported that chlorosis of seedling rice was corrected on calcareous soils in 6 of 15 locations by application of 112 or 336 kg/ha of

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Fe from $Fe_2(SO_4)_3$. Lack of consistent correction of the chlorotic condition was attributed to the presence of soluble salts and high amounts of Na in some soils. The occurrence of chlorosis was more closely correlated with the soil pH and exchangeable Ca than with other routine soil test parameters (10). Place (8) attributed chlorosis of seedling rice to HCO_3 interference of Fe utilization and to an adverse Fe:Mn ratio under submerged conditions. Intermittent draining, to avoid continued submergence, alleviated the chlorotic condition to some extent.

Peterson and Sedberry (7) reported erratic occurrence of "bronzing" which appeared one season but failed to appear the next. Application of Zn or S increased yields significantly. However, "bronzing" appeared later in plant development than does seedling chlorosis reported here.

The purpose of this study was to determine if seedling chlorosis of rice could be corrected by the application of Fe and/or Zn on undisturbed soils with naturally occurring high pH and $CaCO_3$ content.

MATERIALS AND METHODS

Field experiments were conducted for 2 years at different locations on Lake Charles clay soil in the Texas Gulf Coast Rice Belt. Severe chlorosis had reduced rice yields in previous years on the selected sites. Rice cultivar 'Dawn' was planted in 1968 and 'Bluebelle' in 1969. Micronutrient treatments were broadcast on 1.8 × 6.1-m plots after seeding and lightly incorporated into the soil with a hand rake. Treatments were replicated four times. Analysis of the fertilizer grade $Fe_2(SO_4)_3$ and $FeSO_4$ showed the presence of trace amounts of 0.1*N* HCl-soluble Zn (.03% and .006%). The $ZnSO_4$ material contained [illegible] of 0.1*N* HCl-soluble Fe. During the growing season a total application of 154-27-12 kg/ha of N-P-K was applied the first year and 134-21-10 the second year.

Composite soil samples from the chlorosis areas and adjacent normal rice-producing areas in the same field were taken during seedbed preparation at 0 to 15 cm, dried at 35 C and ground to pass a 2-mm sieve. The K, Ca, Mg, Na and Mn were extracted with 1.1*N* $(NH_4)OAc$ (pH 4.2) and Zn and Fe with DTPA-TEA (W. L. Lindsay and W. A. Norvell, personal communication). Phosphorus was extracted with dilute acid-fluoride and analyzed colorimetrically (6).

Plant samples were collected from the most recently matured leaf at the tillering stage of growth, dried at 70 C, ground in a stainless steel mill to pass a 20-mesh sieve, and dry-ashed. Cation analysis on the soil extracts and tissue samples was determined with an atomic absorption spectrophotometer. Phosphorus in the tissue samples was determined by a molybdenum blue method (2).

The CO_3, HCO_3 and E.C. (electrical conductivity) were determined on saturation extracts (11). The pH of soil pastes was measured with glass-calomel electrodes.

A center portion (0.9 × 4.9 m) of the plots was hand harvested and threshed with a Vogel thresher. After cleaning and drying, yields of rough rice were determined and are reported on a 14% moisture basis.

Duncan's Multiple Range Test (5% level) was used to determine statistical differences.

RESULTS AND DISCUSSION

Soil Analyses

Chemical analyses of soil samples collected from the two experimental areas where seedling chlorosis occurred and from adjacent areas of normal rice growth are presented in Table 1. [illegible] were [illegible] different from the normal situation. The pH values of soils where seedling chlorosis occurred were from 0.6 to 0.8 units higher than the pH of soils from normal growth areas. The Ca concentration was approximately 2.5 times greater in affected soil than in normal soil; no significant trend in E.C., Na or P was found. The Mg, Mn and K concentrations were lower in chlorosis-affected soils as compared to normal soils. Based on data showing a lack of yield increases from materials supplying these elements (D. G. Westfall, W. B. Anderson, R. J. Hodges and N. S. Evatt, unpublished data), it is concluded that lack of Mg, Mn or K was not a limiting growth factor. No trend in the Fe:Mn ratio was evident to suggest the existence of an adverse Fe:Mn ratio that might affect seedling growth.

Table 1. Soil analysis results from areas of chlorotic and normal rice growth.

Cultivar and area	pH	EC	Ca	Mg	Mn	Na	K	P	Fe	Zn	CO_3	HCO_3
		mmhos/cm	ppm									
Dawn (1968)												
Seedling chlorosis	7.5	0.90	11,370	452	25	124	140	16	13	4.7	0	106
Normal growth	6.7	0.92	4,430	678	32	137	231	26	46	12.7	0	39
Bluebelle (1969)												
Seedling chlorosis	7.4	1.61	11,170	370	16	271	137	16	16	1.7	0	59
Normal growth	6.8	1.33	4,200	545	30	296	162	18	32	3.2	0	29

A marked difference in DTPA extractable Zn and Fe was observed between soil where chlorosis and normal growth occurred (Table 1). Extractable Fe was lower where seedling chlorosis occurred in both experiments. Zinc levels were also lower in soils from chlorotic areas than from normal areas. However, there was a large difference in extractable Zn between the two experimental sites, and the normal level of one was lower than the level where seedling chlorosis occurred in the other. This same anomaly has been encountered in soil analysis data from other areas with Fe as well as Zn. For this reason, it is difficult to set an absolute value for a soil test rating. This suggests it may be more meaningful to analyze paired soil samples from affected and normal growth areas and evaluate them on a comparative rather than on an absolute value of Fe or Zn. Current soil tests are inadequate to measure and predict Fe and Zn availability under these soil conditions.

The HCO_3 content of saturation extracts was consistently higher from the seedling chlorosis area than from the normal growth area. Detrimental effects of HCO_3 on the growth of rice has been reported previously (4, 8, 10), but no agreement exists on the actual mechanism of its antagonistic effect on growth. It is generally concluded, however, that HCO_3 plays a part in Fe uptake and/or metabolism.

Similar differences in pH and concentrations of Ca, Zn, Fe and HCO_3 have been observed between other chlorotic and normal rice-producing soils. Utilization of comparative values of pH, Ca, Zn, Fe and HCO_3 has proven successful in determining where a response to applications of Fe and/or Zn will occur.

Micronutrient Responses

Visual observations of young rice plants indicated that only the highest rates of Fe sulfate, alone or in combination with Zn, had a beneficial effect on growth. Young seedlings maintained their green color and tillered promisely in both experiments. Plant populations were reduced as much as 90% by treatments which did not control seedling chlorosis.

Plants which survived to the 5-leaf stage of growth appeared to outgrow the chlorotic symptoms. Even

though chlorosis disappeared, plants which had been affected in the seedling stage matured several days later, were shorter in height, and had fewer tillers than plants not suffering from seedling chlorosis.

Leaf samples were collected for tissue analysis at the tillering stage of growth. Since no significant differences in nutrient element levels were evident, only representative data are presented (Table 2). This lack of influence on nutrient content was quite unexpected, particularly where high rates of Fe and Zn were applied at seeding, about 35 days before sampling. Failure of plant tissue to reflect applied Fe and Zn casts skepticism on the validity of rice fertilizer recommendations based only on plant analyses. Nevertheless, the visually observed response to high rates of Fe and Zn early in the prevention of chlorosis and maintenance of plant population was substantiated by significant yield increases (Tables 3 and 4).

The maximum grain yield of 4,670 kg/ha was obtained with an application of 112 kg/ha of Fe plus 12.1 kg/ha of Zn (Table 3). Significant grain yield increases were also obtained from a high rate of Fe and from a lower combination rate of Fe plus Zn. The low rates of Fe or Zn did not significantly increase yields.

The following year the number of Fe and Zn treatments used were increased to include $FeSO_4$ and organic sources (Table 4). The maximum grain yield of 4323 kg/ha was obtained with an application of 100 kg/ha of Fe (from $Fe_2(SO_4)_3$). Comparable yield responses of the higher rates of $Fe_2(SO_4)_3$ and $FeSO_4$, both in combination with $ZnSO_4$ or alone, indicate that $Fe_2(SO_4)_3$ and $FeSO_4$ are equally effective where seedling chlorosis exists. At the tillering stage of growth, plants in the plots that received $Fe_2(SO_4)_3$ were greener in color than those that received $FeSO_4$.

Contamination of Zn in the Fe sulfates and Fe in the $ZnSO_4$ probably played a part in correcting the micronutrient deficiency. Its actual significance was not quantitatively known, but since yields from low rates of Fe/Zn sulfate were comparable with high Fe sulfate alone, a deficiency of Fe and Zn was indicated. Some acidification of a soil may result from addition of Fe sulfate (11). This undoubtedly occurred with the high rate used, and possibly increased the availability of native Fe and Zn. Its significance to yield is difficult to determine but may have affected the results.

Two Zn polyflavonoid materials applied at equivalent rates of Zn resulted in a yield response from Zn polyflavonoid material A but not from polyflavonoid material B. This indicates a difference in availability under these soil conditions.

The Zn-EDTA was applied alone and in combination with Fe-EDDHA, which is more stable at high soil pH values than any other Fe chelates. The results were compared with chelated Fe and Zn from NTA (nitrilotriacetic acid) (Table 4). No significant differences were obtained.

Since adequate sulfur should have been applied by the $(NH_4)_2SO_4$ N fertilizer source, any S response from Fe or Zn sulfate would be doubtful. Also, previous research by the authors has revealed that a response to S applied at seeding is not obtained.

Table 2. Tissue analysis of the most recently matured leaf collected at the late tillering stage of growth from selected treatments in 1969 (cultivar 'Bluebelle').

Treatment	K	Ca	Mg	P	Mn	Zn	Fe
kg/ha	%				ppm		
560 $Fe_2(SO_4)_3$	1.91	0.27	0.21	0.29	134	35	67
250 $Fe_2(SO_4)_3$ + 13.5 $ZnSO_4$	1.84	0.27	0.21	0.31	121	32	76
Check	1.87	0.29	0.24	0.32	115	33	71

Table 3. Influence of Fe and Zn on the yield and maturity of rice grown on an alkaline soil in 1968 (cultivar 'Dawn').

Treatment	Material	Elemental	Yield	Relative maturity
	kg/ha			days
$Fe_2(SO_4)_3$ + $ZnSO_4$	560 + 33.6	112 Fe + 12.1 Zn	4,670 a*	9
$Fe_2(SO_4)_3$	560	112 Fe	4,453 ab	4
$Fe_2(SO_4)_3$ + $ZnSO_4$	280 + 11.2	56 Fe + 4 Zn	4,315 ab	8
$Fe_2(SO_4)_3$	280	56 Fe	3,313 abc	2
$ZnSO_4$	33.6	12.1 Zn	3,051 bc	5
$ZnSO_4$	11.2	4 Zn	3,028 bc	4
Check	0	0	2,716 c	0

* Duncan's Multiple Range (5%).

Table 4. Influence of Fe and Zn on the yield of rice grown on an alkaline soil in 1969 (cultivar Bluebelle).

Treatment	Material	Elemental	Yield
	kg/ha		
$Fe_2(SO_4)_3$	500	100 Fe	4,323 a†
$FeSO_4$ + $ZnSO_4$	250 + 13.5	50 Fe + 4.9 Zn	3,939 ab
$Fe_2(SO_4)_3$ + $ZnSO_4$	250 + 13.5	50 Fe + 4.9 Zn	3,937 ab
$Fe_2(SO_4)_3$ + $ZnSO_4$	100 + 13.5	20 Fe + 4.9 Zn	3,748 abc
$FeSO_4$	500	100 Fe	3,718 abcd
Zn Poly*	16.6	2 Zn	3,523 bcde
$FeSO_4$ + $ZnSO_4$	100 + 13.5	20 Fe + 4.9 Zn	3,413 bcde
Fe-EDDHA + Zn-EDTA	6.33 + 1.76	0.5 Fe + 0.25 Zn	3,395 bcde
Zn-NTA-2	13.8	1 Zn	3,377 bcdef
$ZnSO_4$	39	14 Zn	3,143 cdef
Fe-NTA-2 + Zn-NTA-2	6.41 + 3.47	0.5 Fe + 0.25 Zn	3,142 cdef
$ZnSO_4$	13.5	4.9 Zn	3,045 cdef
Fe Poly + Zn Poly*	8.29 + 4.14	1 Fe + 0.5 Zn	3,007 cdef
Zn-EDTA	7.04	1 Zn	2,924 defg
Fe Poly + Zn Poly†	1.11 + 5	1 Fe + 0.5 Zn	2,736 efg
Zn Poly†	20	2 Zn	2,593 fg
Check	0	0	2,193 g

* Polyflavonoid material A. † Polyflavonoid material B. ‡ Duncan's Multiple Range (5%).

Considerable variation in date of maturity was observed among treatments. The Fe and Zn combination treatments matured 8 and 9 days before the check plot (Table 3). Application of Fe or Zn separately enhanced early maturity irrespective of a significant increase in yield. Maturity ratings were not made in 1969, but trends similar to 1968 were noted. Treatments which gave a significant yield response, particularly those containing $Fe_2(SO_4)_3$, $FeSO_4$, and $ZnSO_4$, matured before other treatments.

Early maturity can be very important if a ratoon (second) crop is to be obtained the same growing season. In the Gulf Coast Region, low temperatures and reduced sunlight in the fall are major factors which limit yields of the ratoon crop. An earlier maturity of 7 to 9 days on the first crop can result in as much as a 10 to 15% increase in yield of the ratoon crop (J. W. Stansel, personal communication). Consequently, this earlier maturity gives an even more promising potential under a ratoon cropping system than for a first crop only, as reported in this paper.

SUMMARY

Soils where rice seedling chlorosis occurred were higher in pH, Ca and HCO_3 and lower in Fe and Zn than soils where normal growth occurred. Comparison of these values between chlorotic and normal soil areas has proven successful in determining the need for Fe and Zn.

High rates of Fe, in the sulfate form, are effective in correcting rice seedling chlorosis. When Zn was applied in combination with Fe, the rate of Fe could be reduced by 50%, and comparable yields were obtained. Zn alone did not give maximum yield responses.

Low rates of several chelated and polyflavonoid materials were not as effective in correcting seedling chlorosis and producing yield responses as were higher rates of Fe or Fe plus Zn from sulfate sources. Acidification of the soil upon the addition of $Fe_2(SO_4)_3$ and $FeSO_4$ may partially account for the apparent superiority of these inorganic sources of Fe over organic sources.

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Paraffin Oil and Granules as Carriers for Trifluralin[1]

D. N. Weaver, R. E. Meyer, and M. G. Merkle[2]

ABSTRACT

This study was conducted to determine the effects of the carrier on the stability of trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) at the soil surface. Trifluralin concentrations were determined with a gas chromatograph equipped with an electron-capture detector. In the laboratory, more trifluralin disappeared from wet soil (80% field capacity) after 24 hours when applied in water than when applied in paraffin oil. At 0 to 20% field capacity there was no difference between the carriers. Vapor sampling experiments showed no detectable volatilization of trifluralin from air dry soil over a 24-hour period at 38C, and confirmed that less volatilization of the herbicide occurred from wet soil when applied in paraffin oil than when applied in water. About 20% less trifluralin was lost from granules than from aqueous sprays on wet clay soil, but no difference occurred on dry soil.

In field, paraffin oil delayed the loss of trifluralin from wet soil (60% field capacity), but under relatively dry field conditions there was little difference between the effectiveness of water and paraffin oil carriers.

Additional index words: Herbicide carriers, Herbicide persistence, Paraffin oil, Trifluralin.

MECHANICAL incorporation into the soil within 48 hours after application of trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) is recommended to minimize loss of the herbicide. Trifluralin is lost from an undisturbed soil surface by volatilization and photodecomposition (1, 4).

This study was conducted to investigate the possibility of using paraffin oil or granules as carriers to lengthen the persistence of trifluralin on the soil surface. If losses of trifluralin from the soil surface could be reduced, the user would have more flexibility in time of incorporation for either ground or aerial applications.

MATERIALS AND METHODS

Effects of Soil Moisture on the Persistence of Trifluralin Applied in Water or Paraffin Oil. We placed 50 g of Miller clay soil in Pyrex Petri dishes and added water as necessary to give moisture contents equivalent to 0 (air dry), 20, and 80% field capacity. All samples were sprayed with 1.12 kg/ha (1 lb/acre) of trifluralin in 80 liters/ha (8.5 gal/acre) of water or paraffin oil. The oil used was a light, white mineral oil (viscosity, SUS @ 100F — 125/135). A laboratory sprayer described by Bouse and Bovey (2) was used. Some of the samples were extracted chemically immediately and stored in a refrigerator for analysis. These were the 0-hour samples. The remaining samples were placed in a growth chamber for 24 hours. The temperature was maintained at 27C and the relative humidity was 50% ± 15%. The chamber was equipped with fluorescent and incandescent lights. Light intensity was 16,200 lux.

For chemical extraction, the entire 50-g soil sample was transferred into a 500-ml Erlenmeyer flask, and sufficient water was added to form a slurry. The herbicide was extracted with two 100-ml portions of diethyl ether. The combined ether extracts were concentrated to approximately 50 ml and brought to 100 ml with hexane.

The extract was analyzed with a Barber-Colman Model 5360[3] gas chromatograph equipped with a radium-226 electron capture detector. A 1.9-m spiral glass column which had an inside diameter of 4 mm was packed with 10% DC-200-mesh Gas-Chrom Q.[3] The temperatures of the injector, column and detector were 250, 210 and 235 C, respectively. The flow rate of the carrier (prepurified nitrogen) was approximately 90 ml/min. The herbicide content of the samples was determined by comparison of peak heights to peak heights produced by a known concentration of trifluralin. The same extraction and analysis techniques were used in subsequent studies. All laboratory experiments were conducted twice and the data combined.

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