Reb 1/1/1940

JOURNAL

OF THE

AMERICAN SOCIETY OF AGRONOMY

9086

VOLUME 32

1940

PUBLISHED BY THE SOCIETY

grasslands in southern and western Wisconsin, further duration of such benefits was dependent on managerial treatment. With moderate grazing or its equivalent, weeds were reduced 92.5% and white grubs 75.2% in 1939 on the portions of nine pastures renovated in 1934 and 1935, when compared with adjacent unrenovated portions of equal area. With excessive grazing on five pastures such weed reductions averaged 53.8% and the white grub control was only 58.2% in 1939.

LITERATURE CITED

1. GRABER, L. F. Improvement of permanent bluegrass pastures with sweet clover. Jour. Amer. Soc. Agron., 19:994–1006. 1927.
2. ————. Evidence and observations on establishing sweet clover in permanent bluegrass pastures. Jour. Amer. Soc. Agron., 20:1197–1205. 1928.
3. ————. Renovating bluegrass pastures. Wis. Col. Agr. Cir. 277. 1936.
4. FUELLEMAN, R. F., and GRABER, L. F. Pasture renovation in relation to populations of white grubs. Jour. Amer. Soc. Agron., 29:186–196. 1937.
5. ————, ————. Renovation and its effect on the populations of weeds in pastures. Jour. Amer. Soc. Agron., 30:616–623. 1938.

TOXIC LIMITS OF REPLACEABLE ZINC TO CORN AND COWPEAS GROWN ON THREE FLORIDA SOILS[1]

O. E. GALL AND R. M. BARNETTE[2]

THE practical use of zinc compounds for the prevention and correction of the malnutrition of a number of plants growing under a variety of soil conditions has been reported during the past decade. In Florida, Allison (1),[3] Allison, Bryan, and Hunter (2), and Allison and Hunter (3) obtained responses to zinc with corn, peanuts, and many other crops grown in the raw peat soils of the Everglades. Mowry (13) and Mowry and Camp (14) found that "bronzing" of tung trees, a malnutrition of *Aleurites fordii* and related species growing in the mineral soils of central, north, and northwest Florida, was due to a deficiency of available zinc in these soils. Also, Blackmon (7) reported the beneficial effects of zinc sulfate for the correction and prevention of "rosette" of pecans and the malnutrition of related nut species growing on mineral soils in the same area.

Barnette and Warner (4) and Barnette, *et al.* (5) reported the use of zinc sulfate for the prevention of "white bud" of corn as well as the malnutrition of velvet beans, cowpeas, millet, and other agronomic crops grown on the mineral soils of Florida. Camp (9) extended the use of zinc sulfate, mostly in the form of a zinc spray, for the correction of "frenching" of citrus trees. "Frenching" of citrus trees occurs both where there is an excess of lime in the soil and in excessively leached, acid soils. Likewise, Townsend (16) found the lack of zinc a cause for failure of beans grown on the newly cleared sawgrass soils at some distance from Lake Okeechobee in the Everglades.

In all the experiments reporting a beneficial effect of zinc, either added to the soil or used as a spray, the quantities added have been relatively small. Thus, 89% zinc sulfate was effective in preventing or correcting the malnutrition of a number of plants when applied at the rate of 5 to 20 pounds per acre in the row for agronomic crops, or ½ to 1 pound per tree (30 to 60 pounds per acre) for tree crops and even smaller quantities were sufficient when added in the form of sprays. On the other hand, the toxicity of zinc to plant growth has been abundantly proved, especially in water cultures, making it highly desirable to develop information as to the limits of toxicity of zinc under different soil conditions and for various plants. It is also of value to know methods of alleviating this toxicity.

In this connection, Freytag (11) in 1868 established that zinc replaced or rendered soluble other cations in the soil, including calcium, magnesium, potassium, and sodium. Baumann (6) attributed the great divergence of the toxic limits of zinc obtained by different work-

[1]Contribution from the Department of Chemistry and Soils, University of Florida, Agricultural Experiment Station, Gainesville, Fla. Received for publication October 13, 1939.

[2]Assistant Chemist and Chemist, deceased, respectively.

ers to the wide variations in the fixing power of soils. Thus, a much lower concentration of zinc was toxic in sandy soils than in humus and marl soils. Brenchley (8) concluded from a review of results reported by many workers that insoluble zinc compounds, such as the oxide, carbonate, phosphate, and sulfide, are seldom toxic to plant growth, while the toxic character of soluble zinc compounds at relatively low concentrations in water cultures, sand cultures, and soils with low fixing power has often been shown.

Recently, Jones, *et al.* (12) studied the reaction of zinc sulfate with the soil and concluded that there are three classes of compounds formed, namely, (a) water-soluble zinc compounds, (b) combinations of zinc with the colloidal portion of the soil (replaceable zinc), and (c) water-insoluble and non-replaceable zinc combinations, such as carbonates, phosphates, and other complex compounds. Replaceable zinc may be considered just as active as other replaceable cations in the soil and also toxic to plant growth under certain conditions. For this reason the toxic limits of replaceable zinc rather than that of water-soluble and total zinc have been studied.

EXPERIMENTAL PROCEDURE

The surface soils of a Norfolk sand, an Orangeburg fine sandy loam, and a Greenville clay loam were used for plant studies in the greenhouse. A quantity of each of these soils was air-dried in thin layers in the greenhouse, screened through a 2-mm, round-hole sieve, and thoroughly mixed.

The procedure for establishing the cultures was the same as that used by Jones, *et al.* (12). A portion of each of the screened surface soils was placed in 3-gallon coffee urn pots and treated with a concentrated zinc sulfate solution. Additional water was added to insure a contact of the zinc sulfate with all the soil. After standing in this condition for a week all salts in free solution were washed out of the soils with distilled water. Frequent tests for sulfate were made in the leachates and the washing discontinued when a negative test was obtained. Then the soils were again spread in thin layers and air-dried in the greenhouse.

The soils treated in this manner were practically saturated with replaceable zinc. The replaceable zinc contents of the three types were 1.376, 1.896, and 2.692 M.E. per 100 grams of air-dried soil[4] for the Norfolk sand, Orangeburg fine sandy loam and Greenville clay loam, respectively. Replaceable zinc was determined by the method of Cone and Cady (10) as modified by Jones, *et al.* (12).

Small glazed earthenware pots holding 1,200 grams of soil were used for the study of the toxicity of replaceable zinc. Cultures with a range of concentration of replaceable zinc were established by combining different proportions of the untreated and zinc-saturated soils. The soils were fertilized with chemically pure salts as indicated in the tables. Duplicate cultures were established for each of the soil treatments used. Corn and cowpeas were used as test plants. Ten seed of Whatley's prolific corn and of Suwannee cowpeas were planted in each of the pots. Upon germination and establishment of the seedlings, they were thinned to a uniform stand of five plants in each culture. Visually optimum moisture conditions for plant growth were maintained by frequent weighings and additions of distilled water. Each planting of corn or cowpeas was grown for approximately one month. The plants in each pot were harvested by severing the tops from the roots at the soil level. The plants were dried at 100° C. The roots were removed from the soil in the pots before another crop was planted.

EXPERIMENTAL RESULTS

Two crops of corn and two of cowpeas were grown in rotation in each of the soils used for the experiment.

The average relative weights of the corn and cowpeas were calculated on the basis of the average dry weights of plants grown in cultures without zinc treatment and fertilized with ammonium nitrate only. The results of these calculations for corn and cowpeas are given in Tables 1 and 2, respectively.

The results obtained with corn indicate that replaceable zinc is definitely toxic to plant growth at a concentration between 0.688 and 1.376 M.E. per 100 grams of air-dried Norfolk sand. The lower limit of this range of replaceable zinc was slightly toxic while the higher limit was definitely toxic. The use of 233 pounds per acre of mono-calcium phosphate did not significantly influence this range, though 1,000 pounds per acre of calcium carbonate reduced the toxicity of replaceable zinc in the culture containing 1.376 M.E. of replaceable zinc from 32% of the growth with no added replaceable zinc in the ammonium nitrate cultures to 63% in the ammonium nitrate cultures with calcium carbonate.

Lott (15) has recently shown that by lowering the hydrogen-ion concentration with additions of calcium carbonate, zinc toxicity is alleviated. It is noted that in the presence of either mono-calcium phosphate or calcium carbonate a considerable amount of replaceable zinc (0.206 M.E. or 135 pounds zinc per acre), causes a stimulation in plant growth. Unfortunately, the Norfolk sand cultures were not established so as to give a range suitable for determining more exactly the toxic limits at the higher concentrations of replaceable zinc.

The results obtained with corn at different concentrations of replaceable zinc in the Orangeburg fine sandy loam indicate that 0.758 to 1.137 M.E. of replaceable zinc per 100 grams of air-dried soil were toxic in the series of cultures with ammonium nitrate alone; the series with 1,800 pounds mono-calcium phosphate in addition showed the same range of toxicity. On the other hand, with additions of ammonium nitrate plus 4,000 pounds per acre of calcium carbonate, toxicity was shown to be within the range of 1.137 and 1.516 M.E. of replaceable zinc per 100 grams of soil. Also, with the highest concentration of 1.896 M.E. of replaceable zinc per 100 grams of air-dried soil, the 4,000 pounds per acre application of calcium carbonate decreased the toxicity to corn by an increased yield that varied from 32% without the carbonate to 61% with the carbonate. In this soil type a positive response of corn to the application of mono-calcium phosphate was noted with the lower concentrations of replaceable zinc.

The nature of these experiments precludes the determination of a

TABLE 1.—*The effect of increasing quantities of replaceable zinc in the soil on the growth of corn.*

Applications of fertilizing salts per acre	Relative yields of corn								
	Norfolk sand								
	0.000	0.069*	0.138	0.206	0.275	0.482	0.688	1.376
00 lbs NH_4NO_3	100 (0.89 gram)†	95	92	89	96	93	85	32
00 lbs. NH_4NO_3 and 233 lbs. $CaH_4(PO_4)_2$	92	98	99	113	105	95	96	34
00 lbs. NH_4NO_3 and 1,000 lbs. $CaCO_3$	90	97	99	103	96	95	93	63
	Orangeburg fine sandy loam								
	0.000	0.047*	0.095	0.189	0.379	0.758	1.137	1.516	1.896
50 lbs. NH_4NO_3	100 (0.87 gram)†	101	87	94	93	81	62	56	32
50 lbs. NH_4NO_3 and 1,800 lbs. $CaH_4(PO_4)_2$	131	125	127	134	120	98	65	62	37
50 lbs. NH_4NO_3 and 4,000 lbs. $CaCO_3$	104	87	93	98	98	86	83	73	61
	Greenville clay loam								
	0.000	0.067*	0.134	0.269	0.538	1.077	1.615	2.153	2.692
50 lbs. NH_4NO_3	100 (0.91 gram)†	108	116	121	116	100	88	67	42
50 lbs. NH_4NO_3 and 1,800 lbs. $CaH_4(PO_4)_2$	148	138	143	151	128	115	89	63	42
50 lbs. NH_4NO_3 and 4,000 lbs. $CaCO_3$	123	115	109	108	105	109	100	84	70

*M.E. of replaceable zinc per 100 grams of air-dried soil. For converting M.E. per 100 grams soil to pounds of zinc per acre multiply by 654.
†Average oven-dried weights of plants grown with ammonium nitrate without addition of replaceable zinc used as a basis for calculation of all relative yields.

TABLE 2.—*The effect of increasing quantities of replaceable zinc in the soil on the growth of cowpeas.*

Applications of fertilizing salts per acre	Relative yield of cowpeas								
	Norfolk sand								
	0.000	0.069*	0.138	0.206	0.275	0.482	0.688	1.376
00 lbs. NH_4NO_3	100 (0.99 gram)†	96	91	86	92	71	61	25
00 lbs. NH_4NO_3 and 233 lbs. $CaH_4(PO_4)_2$	99	96	90	82	94	74	61	35
00 lbs. NH_4NO_3 and 1,000 lbs. $CaCO_3$	120	104	104	94	96	94	72	52
	Orangeburg fine sandy loam								
	0.000	0.047*	0.095	0.189	0.379	0.758	1.137	1.516	1.896
0 lbs. NH_4NO_3	100 (1.5 gram)†	114	113	106	91	54	22	16	12
0 lbs. NH_4NO_3 and 1,800 lbs. $CaH_4(PO_4)_2$	112	118	113	117	93	71	26	13	14
0 lbs. NH_4NO_3 and 4,000 lbs. $CaCO_3$	101	98	109	111	100	103	93	90	74
	Greenville clay loam								
	0.00	0.067*	0.134	0.269	0.538	1.077	1.615	2.153	2.692
0 lbs. NH_4NO_3	100 (1.27 gram)†	95	101	93	92	72	36	21	17
0 lbs. NH_4NO_3 and 1,800 lbs. $CaH_4(PO_4)_2$	112	106	111	131	99	59	30	22	14
0 lbs. NH_4NO_3 and 4,000 lbs. $CaCO_3$	118	96	116	107	91	93	71	50	34

*M.E. of replaceable zinc per 100 grams of air-dried soil. For converting M.E. per 100 grams of soil to pounds per acre multiply by 654.
†Average oven-dried weights of plants grown with ammonium nitrate without addition of replaceable zinc used as a basis for calculation of all relative yields.

placeable zinc may begin to be toxic has been used. The higher limits of this range have been set at the concentration of replaceable zinc which will decrease the plant yields at least 25%. Logically the lower limits become the next lower concentration.

The Greenville clay loam showed that the amounts of replaceable zinc toxic to corn in the series with 150 pounds of ammonium nitrate alone were between 1.615 and 2.153 M.E. per 100 grams of air-dried soil. The same limits were observed for the series with ammonium nitrate plus mono-calcium phosphate. On the other hand, the toxic limits for the series of cultures treated with ammonium nitrate plus calcium carbonate were between 2.153 and 2.692 M.E. of replaceable zinc per 100 grams of air-dried soil. In addition to these observations, a definite increase in yields of corn plants with the application of mono-calcium phosphate to Greenville clay loam was noted with the cultures having the lower concentrations of replaceable zinc. The lower concentrations of replaceable zinc stimulated plant growth in the cultures with ammonium nitrate alone as well as in those with ammonium nitrate plus calcium carbonate.

The toxic limits of replaceable zinc for cowpeas were observed to be distinctly lower than for corn (Table 3). In the Norfolk sand cultures, the toxic limit for cowpeas was between 0.275 and 0.482 M.E. of replaceable zinc per 100 grams of soil in the ammonium nitrate and in the combination ammonium nitrate and mono-calcium phosphate treatments. On the other hand, the limits for the ammonium nitrate-calcium carbonate cultures were between 0.482 and 0.688 M.E. per 100 grams. Likewise, the carbonate increased the plant growth through the entire range of replaceable zinc concentrations.

TABLE 3.—*The toxic range of replaceable zinc for corn and cowpeas.*

Applications of fertilizing salts, per acre	M. E. of replaceable zinc per 100 grams of air-dried soil toxic to	
	Corn	Cowpeas
Norfolk Sand		
100 lbs. NH_4NO_3	0.688–1.376	0.275–0.482
100 lbs. NH_4NO_3 and 233 lbs. $CaH_4(PO_4)_2$	0.688–1.376	0.275–0.482
100 lbs. NH_4NO_3 and 1,000 lbs. $CaCO_3$	0.688–1.376	0.482–0.688
Orangeburg Fine Sandy Loam		
150 lbs. NH_4NO_3	0.758–1.137	0.379–0.758
150 lbs. NH_4NO_3 and 1,800 lbs. $CaH_4(PO_4)_2$	0.758–1.137	0.379–0.758
150 lbs. NH_4NO_3 and 4,000 lbs. $CaCO_3$	1.137–1.516	1.516–1.896
Greenville Clay Loam		
150 lbs. NH_4NO_3	1.615–2.153	0.538–1.077
150 lbs. NH_4NO_3 and 1,800 lbs. $CaH_4(PO_4)_2$	1.615–2.153	0.538–1.077
150 lbs. NH_4NO_3 and 4,000 lbs. $CaCO_3$	2.153–2.692	1.077–1.615

The toxic limit of replaceable zinc for cowpeas in the Orangeburg fine sandy loam was between 0.379 and 0.758 M.E. for the cultures

ammonium nitrate and mono-calcium phosphate. However, the addition of phosphate stimulated the growth of the cowpeas in the lower zinc applications. The toxic limit of concentration was increased to between 1.516 and 1.896 M.E. of replaceable zinc per 100 grams by an application of 4,000 pounds per acre of calcium carbonate. The toxicity in the cultures with 1.896 M.E. of replaceable zinc per 100 grams of air-dried soil was very materially reduced by the calcium carbonate.

With the Greenville clay loam a concentration somewhere between 0.538 and 1.077 M.E. of replaceable zinc per 100 grams of soil proved toxic to cowpeas in the cultures with ammonium nitrate and mono-calcium phosphate, while the range for the cultures receiving calcium carbonate was between 1.077 and 1.615 M.E. Both treatments receiving mono-calcium phosphate and calcium carbonate, respectively, showed stimulated growth with the lower concentrations of replaceable zinc.

The toxic limits of replaceable zinc for corn and cowpeas grown in a Norfolk sand, an Orangeburg fine sandy loam, and a Greenville clay loam with ammonium nitrate, ammonium nitrate plus mono-calcium phosphate, and ammonium nitrate and calcium carbonate are summarized in Table 3. The results indicate that in the Norfolk soil the point of toxic limit to plants falls nearer the lower than the upper limits of the ranges used.

The quantities of replaceable zinc necessary to be toxic to corn increased with an increase in the total replaceable zinc content of the soils. In other words, the toxic limits were raised with an increase in the quantity of replaceable zinc held in the soil, being at a lower range in Norfolk sand and increasing in the Orangeburg fine sandy loam and Greenville clay loam. Mono-calcium phosphate did not change these ranges. Calcium carbonate, however, materially increased the quantity of replaceable zinc necessary to be toxic to corn.

The germination of corn was not decreased by replaceable zinc but growth was slow above toxic concentrations. At these concentrations, the leaves turned yellow between the veins, while the veins themselves remained intensely green. The rate of growth in these cultures was greatly reduced and the plants remained small in comparison with the other cultures where zinc was not present in toxic concentrations.

In the absence of calcium carbonate the toxic concentrations of zinc were very much lower for cowpeas than for corn. Under these conditions of treatment the point of toxic concentration for the Norfolk sand fell somewhere in the concentration range of 0.275 to 0.482 M.E. of replaceable zinc per 100 grams of air-dried soil, that for the Orangeburg fine sandy loam between 0.379 and 0.758 M.E., and that for Greenville clay loam between 0.538 and 1.077 M.E., respectively. It is thus seen that definitely larger quantities of replaceable zinc were required to produce toxic effects on cowpeas in the heavier soils than on the lighter types. Calcium carbonate increased the amount of replaceable zinc necessary to cause toxicity in all three types. This shows the effect of calcium carbonate in overcoming, or at least alleviating, the toxic properties of large quantities of replaceable

Cowpea seedlings were severely stunted by toxic concentrations of replaceable zinc. Examination of the roots at the toxic concentrations of the three soils showed that nodulation had been decreased at the lower limits of toxicity and prohibited at the higher limits. The germination was not affected by the toxic concentrations of replaceable zinc but growth was slow with the formation of only two to four leaves. These stunted plants remained green until the edges of the leaves began to curl and die. Just before harvest, part of the dead leaves dropped from the stunted plants, but the plants remained alive until harvest.

A series of such cultures grown in the Orangeburg fine sandy loam with various quantities of replaceable zinc, with and without calcium carbonate, are shown in Fig. 1. The beneficial effects of calcium carbonate in preventing the extreme toxicity may be noted.

SUMMARY

Soluble zinc compounds are used under a variety of conditions in Florida to prevent or correct malnutrition of a number of plants caused by a deficiency of available zinc. The zinc accumulates in the

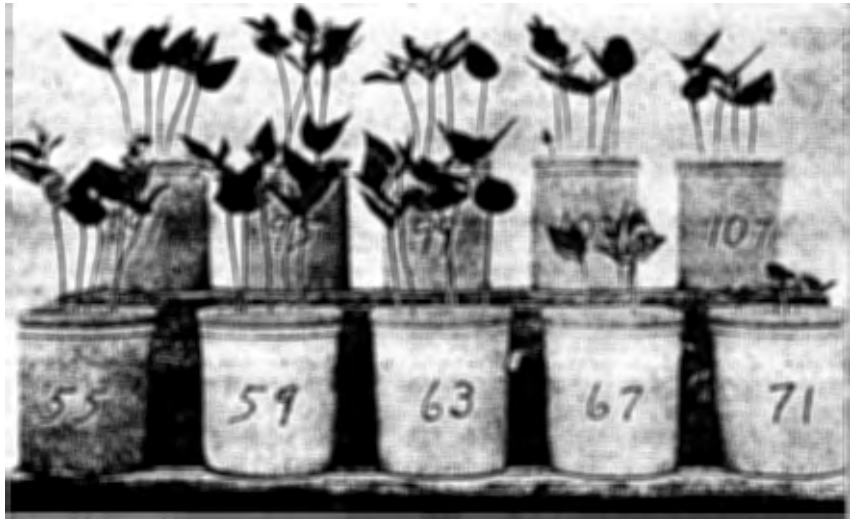

FIG. 1.—The effect of replaceable zinc on the growth of Suwanee cowpeas in Orangeburg fine sandy loam.

M.E. replaceable zinc per 100 grams of soil	Replaceable zinc and ammonium nitrate, pot No.	Replaceable zinc, ammonium nitrate, and 4,000 lbs. per acre $CaCO_3$ pot No.
None	55	91
0.095	59	95
0.379	63	99

soil either in the mobile replaceable form or in definite water-insoluble forms. The former is known to be toxic to plant growth when it accumulates in sufficient quantities; the latter are seldom toxic to plant growth. In order to establish the toxic limits of zinc for certain plants and to determine methods of preventing or alleviating this toxicity, three series of greenhouse cultures were employed.

A simple but expedient method is described for preparing greenhouse cultures for the above purpose with a Norfolk sand, an Orangeburg fine sandy loam, and a Greenville clay loam, giving ranges of replaceable zinc in the soils. The principal feature of the technic is the use of soils which had been previously saturated with replaceable zinc and washed free from soluble salts, combined in varying proportions with the corresponding air-dried untreated soils to give a suitable range in concentration of replaceable zinc in each soil.

Two crops of corn and cowpeas as test plants were grown for four weeks each in rotation. The weight of the dry plants from each culture was obtained. The results of the tests may be summarized as follows:

1. Replaceable zinc became toxic to corn on a Norfolk sand between the concentrations of 0.688 and 1.376 M.E. per 100 grams (451–902 pounds Zn per acre); between 0.758 and 1.137 M.E. (497–734 pounds Zn per acre) on an Orangeburg fine sandy loam; and between 1.615 and 2.153 M.E. (1,051–1,402 pounds Zn per acre) on a Greenville clay loam.

2. Replaceable zinc became toxic to cowpeas between the concentrations of 0.275 and 0.482 M.E. per 100 grams (181–316 pounds Zn per acre) on a Norfolk sand; between 0.379 and 0.758 M.E. (246–479 pounds Zn per acre) on an Orangeburg fine sandy loam; and between 0.538 and 1.077 M.E. (351–701 pounds per acre) on a Greenville clay loam.

3. The application of mono-calcium phosphate at the rate of 233 pounds per acre to the Norfolk sand and 1,800 pounds per acre to the Orangeburg fine sandy loam and the Greenville clay loam did not change the toxic limits of the replaceable zinc for corn or cowpeas. The presence of phosphate as a plant nutrient, however, stimulated the growth of corn and cowpeas on the Orangeburg fine sandy loam and the Greenville clay loam, while no effect was noted on the Norfolk sand.

4. The use of calcium carbonate at the rate of 1,000 pounds per acre on the Norfolk sand and 4,000 pounds per acre on the Orangeburg fine sandy loam and the Greenville clay loam definitely increased the concentrations at which replaceable zinc became injurious to corn and cowpeas and greatly alleviated the toxic condition.

LITERATURE CITED

1. ALLISON, R. V. (The effect of various soil treatments with special elements on field crops.) Univ. Fla. Agr. Exp. Sta. Rpt., 112R–114R. 1928.
2. ———, BRYAN, O. C., and HUNTER, J. H. The stimulation of plant response on the raw peat soils of the Florida Everglades through the use of copper sulfate and other chemicals. Univ. Fla. Agr. Exp. Sta. Bul. 190. 1927.
3. ——— and HUNTER, J. H. Response of the peanut plant to treatment of the raw sawgrass peat of the Everglades with a mixture of copper and zinc

4. BARNETTE, R. M., and WARNER, J. D. A response of chlorotic corn to the application of zinc sulfate to the soil. Soil Sci., 39:145–159. 1935.
5. ————, CAMP, J. P., WARNER, J. D., and GALL, O. E. The use of zinc sulfate under corn and other field crops. Univ. Fla. Agr. Exp. Sta. Bul. 292, 1936.
6. BAUMANN, A. Das verhalten von zinksalzen gegen pflanzen und im boden. Die Landw. Versuchstat., 31:1–53. 1895.
7. BLACKMON, G. H. (Response of rosetted nut trees to applications of zinc sulfate.) Univ. Fla. Agr. Exp. Sta. Ann. Rpt., 74–75, 1935.
8. BRENCHLEY, W. E. Inorganic Plant Poisons and Stimulants. London; Cambridge University Press. Ed. 2. (Pages 36–50.) 1927.
9. CAMP, A. F. Studies on the effect of zinc and other unusual mineral supplements on the growth of horticultural crops. Univ. Fla. Agr. Exp. Sta. Ann. Rpt., 81–82, 1936.
10. CONE, W. H., and CADY, L. C. Diphenylbenzidine as an internal indicator for titration of zinc with potassium ferrocyanide. Jour. Amer. Chem. Soc., 49:356–360. 1927.
11. FREYTAG, M. Ueber den einfluss des zinkoxyds und seiner verbindungen auf die vegetation. Mitth. Koenig, Landw. Akad. Poppelsdprf., 82–89. 1868.
12. JONES, H. W., GALL, O. E., and BARNETTE, R. M. The reaction of zinc sulfate with the soil. Univ. Fla. Agr. Exp. Sta. Bul. 298. 1936.
13. MOWRY, HAROLD. Propagation, planting, and fertilizing tests with tung oil trees. Univ. Fla. Agr. Exp. Sta. Ann. Rpt., 91–95. 1933.
14. ———— and CAMP, A. F. A preliminary report on zinc sulfate as a corrective for bronzing of tung trees. Univ. Fla. Agr. Exp. Sta. Bul. 273. 1934.
15. LOTT, W. L. The relation of hydrogen-ion concentration to the availability of zinc in the soil. Soil Sci. Soc. Proc., 3:115–121, 1938.
16. TOWNSEND, G. R. Zinc sulfate sprays for vegetable crops. Univ. Fla. Agr. Exp. Sta. Press Bul. 488. 1936.

THE GERMINATION OF SEED OF *ORYZOPSIS HYMENOIDES*[1]

VIVIAN K. TOOLE[2]

BECAUSE of the difficulty encountered in obtaining satisfactory field stands and laboratory germination of seed of *Oryzopsis hymenoides* (Roem. & Schult.) Ricker, Indian ricegrass, M. M. Hoover of the Soil Conservation Service suggested the study of the germination requirements of this seed.

Huntamer (1)[3] has presented results on the different strains of *Oryzopsis hymenoides*, the nature of the resistance of the seed to germination, and of various treatments to overcome this resistance. She gives a rather complete review of the literature on the distribution of this plant and its value as a forage grass. Stoddart and Wilkinson (2) have published on the treatment of the seed with concentrated sulfuric acid.

METHODS

The seed was furnished by various Soil Conservation agencies through the courtesy of M. M. Hoover. The seed as received was cleaned by means of an air blast blower. The "seed" referred to in this paper is the fruit with the attached lemma and palea. The blown seed was placed in water for 5 minutes to make a more complete separation of the heavy and light seed. Stoddart and Wilkinson (2) concluded that only those seeds which sank in water within 5 minutes had a reasonable chance to grow.

The seed was germinated in duplicate tests of 100 seeds each on various media in Petri dishes. Paper toweling in the Petri dishes was a satisfactory substratum for the treated seeds which germinated quickly. After an extended period in the germinator, the toweling tended to lose its water-absorbing capacity. For this reason, a sandy soil or a mixture of peat and sand in Petri dishes was more satisfactory for non-treated seed that required a long period for germination.

The seed was considered as germinated when it had produced a normally developed root and plumule. The sprouts grew more slowly at the low temperatures, developing into a "stubby" but otherwise normal sprout. In many of the tests of the non-treated seed and of the seed pretreated with approximately 71% sulfuric acid for 30 minutes, the root lacked the vigor to push itself from within the lemma and palea and so grew coiled around the caryopsis. The two types of sprouts just described were counted as germinated. The most common abnormality, both in the treated and non-treated seed, was the lack of root development. Seeds showing this abnormality were not recorded as germinated.

The seed was germinated over a wide range of constant and alternating temperatures. The alternation of temperature was obtained by transferring the test from one chamber to another, the test remaining at the first temperature listed for 17 and at the second temperature for 7 hours daily. The temperature of the germi-

[1]Contribution from the Division of Fruit and Vegetable Crops and Diseases, U. S. Dept. of Agriculture, Washington, D. C. Received for publication October 28, 1939.
[2]Junior Botanist