WHEAT STRAW

Effect of Straw and Certain Salts on Soil Reaction

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Wheat straw is a major crop residue, which is returned to the soil as a conservation practice. It was considered of value to determine the effects of wheat straw upon soil reaction, alone and in the presence of certain salts commonly present in irrigated soils. Before the addition of straw, the soils containing the nitrates of calcium and magnesium were only slightly more acid than soils containing the carbonates of calcium and magnesium. After the addition of straw, soil acidity in the nitrate treatments increased significantly over that in the soils treated with carbonates, even though nitrogen levels in all treatments were equivalent. Sodium nitrate added to soils containing calcium and magnesium nitrates exerted a significant effect in counteracting acidity between 2 and 3 months after the addition of straw. In the absence of other salts, sodium nitrate and straw resulted in greater soil acidity than did straw alone.

THE COMBINED EFFECT of acid fertilizer, straw, and salts upon soil reaction is reported as part of an investigation (*3*) to determine the effect of varying calcium-magnesium ratios on the availability of soil and fertilizer phosphorus. In this latter study sunflowers showed such marked variability in growth that a supplementary study of soil reaction under the various treatments was conducted along with the major investigation. Consequently, the experiment reported here was not designed to be a study of soil reaction under the treatments indicated.

Review of Literature

Considerable research has been done, studying these factors in their individual effects on soil pH, but there appear to be no reports on the combined effects of these three factors. In many cases straw is turned under after a grain crop, and a nitrogen fertilizer is added to aid in its decomposition. Frequently the soils contain varying concentrations and ratios of salts.

There has been considerable work on the effect on soil reaction of adding acid fertilizers. Pierre (*3*) reported the acid reaction resulting from the addition of ammonium sulfate and ammonium nitrate. Both fertilizers decreased the soil pH, with ammonium nitrate exerting the lesser effect. The combination of an acid and basic type of fertilizer prevented the soil from becoming more acid. Harston and Albrecht (*1*) found that plants growing in soil could increase soil pH by more than 2.0 pH units. However, this effect had little significance in plant nutrition.

Comparative use of different fertilizers with a straw mulch was investigated by Mooers *et al.* (*2*), who found the recovery of nitrogen to be greater with sodium nitrate than ammonium sulfate. Waksman and Heukelekian (*5*) in a study of cellulose decomposition found that differences in soil reaction did not inhibit breakdown of cellulose. White *et al.* (*6*), working with cellulose breakdown in three soils, concluded that maximum decomposition took place at pH 7.2.

Changes in soil reaction due to added salts were not permanent under high rainfall and the lower pH values noted were only temporary, according to Salonen (*1*). Addition of calcium sulfate, magnesium chloride, ammonium chloride, calcium chloride, and potassium chloride resulted in lower pH, while calcium carbonate had no effect on the soil reaction.

Procedure

The sandy loam soil used in this study was selected from the university field station at Lewiston, Idaho. The analysis of this soil was as follows: pH, 7.2; total soluble salts, 700 p.p.m.; inorganic carbonates, 0.06%; available phosphoric acid, 65 p.p.m.; and cation exchange capacity, 12.0 meq. per 100 grams. The soil was air-dried, screened, and thoroughly mixed, then 21 pounds was weighed into each of 30 steel cylinders, which had been coated with Biturine paint. The following treatments were then applied, one to each cylinder of soil.

To 12 of the cylinders calcium nitrate

and magnesium nitrate were added in the following calcium-magnesium ratios: 0/0, 4/1, 2/1, 1/1, 1/2, 1/4, 4/0, 2/0, 1/0, 0/1, 0/2, and 0/4. Here, each part was equivalent to 1/8 mole of the element, so that in the case of the 1/4 ratio, 1/8 mole of calcium and 1/2 mole of magnesium were the amounts used. The nitrogen level in each treatment was raised to a common level by addition of increments of ammonium nitrate. To another 12 cylinders of the soil the same calcium-magnesium ratios were applied, only calcium carbonate and magnesium carbonate being used. Ammonium nitrate was added in each case to raise the nitrogen level to that of the former set of treatments. To the remaining six cylinders of soil were added calcium nitrate and magnesium nitrate to supply the following calcium-magnesium ratios: 0/0, 4/1, 2/1, 1/1, 1/2, and 1/4. But 0.2% of sodium as sodium nitrate was included, even in the 0/0 treatment. The soil in this group of treatments is referred to as a sodium soil. The overall nitrogen level was again maintained using ammonium nitrate. To ensure thorough mixing, the added salts and soil were tumbled mechanically in a drum for 5 minutes in each case.

The treated soils in the cylinders were moistened with distilled water to field capacity—that is, 15% water—and left to incubate for 6 weeks. The soils were kept moist.

At the end of the incubation period the soil from each cylinder was again tumbled for 5 minutes, then divided into five 6-inch flower pots. Thus each treatment was divided into five replications, making a total of 150 pots. The pots were randomized on a bench in the greenhouse.

Each pot was then sampled, the soil air-dried, and pH determined on a saturated soil paste using a Beckman line-operated meter. Finely ground wheat straw was then added to each treatment at the rate of 1 ton per acre. The five pots in each treatment were composited and the straw was mixed in by tumbling, and again the treatment was divided into five pots. Two months later the pots were sampled for pH determination. The third and final sampling was taken 1 month later.

Results and Discussion

Effect Of Straw In Table I are shown the effects of straw on the hydrogen ion concentration of a soil irrespective of the amounts of calcium and magnesium added (calcium-magnesium ratios). The data indicate that the nitrates of calcium and magnesium resulted in a higher soil acidity than did the carbonates of calcium and magnesium. Even in the treatments which included 0.2% sodium as sodium nitrate together with calcium and magnesium nitrates, the hydrogen ion concentrations were higher at the first two sample dates—i.e., 0.19×10^{-6} gram of hydrogen ion (pH 6.72) and 7.20×10^{-6} gram of hydrogen ion (pH 5.14)—than were the hydrogen ion concentrations of the calcium and magnesium carbonate treatments without sodium.

The variables in Table I are (1) insoluble salts of calcium and magnesium, such as carbonates; (2) soluble salts of calcium and magnesium, such as nitrates; and (3) soluble salts just mentioned plus soluble sodium nitrate. The highest hydrogen ion concentration, 13.32×10^{-6} gram of hydrogen ion (pH 4.88), was evident 3 months after the addition of straw in the calcium and magnesium nitrate treatments. The effect of the straw on the soil reaction under the influence of the three groups of salt treatments can be noted by comparing the hydrogen ion concentrations in the respective treatments before, 2 months after, and 3 months after the mixing of the soil and straw. Here can be noted the neutralizing effect of the calcium and magnesium carbonates at 2 and 3 months, and the steady upsurge in hydrogen ion concentration under the neutral nitrate salts. In the third case, the sodium apparently is effective sometime before or between 2 and 3 months in partially neutralizing the acidity. Maximum straw decomposition and evolution of carbon dioxide occurred between the second and third months; then the acidity began decreasing.

Effect of Nitrates And Straw In Table II are the interactions of the effects of straw on the soil reaction when the soil carries various ratios of calcium-magnesium added as nitrates. The highest production of hydrogen ion occurred where the calcium-magnesium ratio was 2/0 2 months after the straw application. Hydrogen ion concentration at this

Table I. Effect of Salt Treatments on Soil Reaction[a] before and after Addition fo Straw

Principal Salts[b] Added	Sample: Before	After: 2 mo.	After: 3 mo.	L.S.D.[c] for H Ion Concentrations: 0.05	0.01
	H Ion Concentration, $\times 10^{-6}$ Gram H Ion				
$CaCO_3$ $MgCO_3$	0.05 (7.30)	3.53 (5.45)	3.21 (5.49)	0.80	1.16
$Ca(NO_3)_2$ $Mg(NO_3)_2$	0.62 (6.21)	9.05 (5.04)	13.32 (4.88)	1.42	2.07
$Ca(NO_3)_2$ $Mg(NO_3)_2$ $NaNO_3$	0.19 (6.72)	7.20 (5.14)	2.04 (5.62)	1.42	2.07

[a] Mean values shown for H ion concentration to be considered as "mean $\times 10^{-6}$ gram H ion"; pH values given in parentheses.
[b] NH_4NO_3 added in appropriate amounts to all treatments to maintain common N level throughout experiment.
[c] L.S.D. Difference between means, required for significance at the 5 and 1% levels.

Table II. Effect of Straw, Calcium Nitrate, and Magnesium Nitrate Treatments on H Ion Concentration[a] of a Soil

Sample	Calcium-Magnesium Ratios: 0/0	4/1	2/1	1/1	1/2	1/4	4/0	2/0	1/0	0/1	0/2	0/4
	$\times 10^{-6}$, gram H ion											
Before adding straw	0.30 (6.52)	0.58 (6.24)	0.83 (6.08)	0.89 (6.05)	0.61 (6.71)	0.79 (6.10)	0.96 (6.02)	0.76 (6.12)	0.41 (6.39)	0.43 (6.37)	0.39 (6.41)	0.43 (6.39)
2 mo. after adding straw	6.72 (5.17)	5.94 (5.23)	11.29 (4.95)	14.85 (4.83)	5.40 (5.27)	1.52 (5.82)	6.52 (5.19)	17.83 (4.75)	15.03 (4.82)	15.20 (4.82)	3.24 (5.49)	5.04 (5.30)
3 mo. after adding straw	21.84 (4.66)	2.17 (5.66)	9.61 (5.02)	19.76 (4.71)	24.71 (4.61)	8.95 (5.05)	4.07 (5.39)	9.67 (5.01)	16.28 (4.79)	29.92 (4.52)	9.97 (5.00)	2.84 (5.55)
L.S.D. for interaction	(0.01) = 12.64; (0.05) = 9.54											

[a] Mean values shown for H ion concentration to be considered as "mean $\times 10^{-6}$ gram H ion"; pH values are given in parentheses.

Table III. Effect of Straw, Calcium Carbonate, and Magnesium Carbonate Treatments on H Ion Concentration[a] of a Soil

Sample	Calcium-Magnesium Ratios											
	0/0	4/1	2/1	1/1	1/2	1/4	4/0	2/0	1/0	0/1	0/2	0/4
	$\times 10^{-6}$, gram H ion											
Before adding straw	0.27 (6.57)	0.02 (7.70)	0.03 (7.52)	0.04 (7.40)	0.03 (7.52)	0.02 (7.70)	0.03 (7.52)	0.04 (7.40)	0.06 (7.28)	0.06 (7.28)	0.04 (7.40)	0.03 (7.52)
2 mo. after adding straw	14.56 (4.84)	0.09 (7.05)	0.29 (6.54)	0.92 (6.04)	0.64 (6.19)	0.11 (6.96)	0.26 (6.59)	1.06 (5.97)	9.19 (5.04)	11.57 (4.94)	3.08 (5.51)	0.52 (6.28)
3 mo. after adding straw	13.38 (4.88)	0.17 (6.77)	1.45 (5.84)	3.76 (5.42)	1.80 (5.74)	0.15 (6.82)	0.42 (6.38)	2.81 (5.55)	6.94 (5.16)	4.71 (5.33)	2.61 (5.58)	0.25 (6.60)
L.S.D. for interaction	(0.01) = 2.95; (0.05) = 2.23											

[a] Mean values shown for H ion concentrations to be considered as "mean $\times 10^{-6}$ gram H ion"; pH values are given in parentheses.

ratio was significantly greater than that of the calcium-magnesium ratios 0/2, 0/4, 4/0, 1/4, 1/2, 4/1, and 0/0. Apparently conditions at the 2/0 ratio were most favorable for the production of acid at that time. At the third sampling, the hydrogen ion concentration at that ratio dropped appreciably while acid production increased under other calcium-magnesium ratios, notably 0/1, 1/2, and 0/0. If acid production can be related to straw decomposition, then the data indicate that the presence of calcium, and to a lesser degree of magnesium, accelerates the decomposition of straw. Nitric acid may also be a cause of high acidity.

In the treatment where no calcium and magnesium were present—i.e., 0/0—and with ratios such as 0/1, 1/2, and 1/1, acid production was highest at the third month or later, whereas acid production in other treatments appeared to be declining after the second month. In these treatments—4/1, 2/1, 4/0, 2/0, and 0/4—it is conceivable that the peak acid production was attained somewhere in the first 2 months.

Effect of Carbonates And Straw

In Table III are the interactions of the effects of straw on the soil reaction when the soil carries various ratios of calcium-magnesium added as carbonates. This group of treatments carried the same amount of nitrogen as did the group of nitrate treatments shown in Table II. In this case is shown the importance of these relatively insoluble calcium and magnesium carbonates in controlling soil reaction even when adequate nitrogen is present. Maximum hydrogen ion concentration at the 2- and 3-month samplings was in the treatment carrying no calcium or magnesium—i.e., 0/0. This implies that the alkaline nature of the calcium carbonate and magnesium carbonate tends to neutralize the acidity while the latter is being produced. Treatments showing the highest acidity are the 1/0 and 0/0 ratios at the 2-month sampling. Hydrogen ion concentrations in these treatments are significantly lower than that produced in the 0/0 treatment. Nevertheless, the acidity in those two treatments is very significantly higher than the acidity produced in the other calcium-magnesium treatments.

Effect of Straw, Nitrates, and Sodium On Soil Reaction

In Table IV are the means for the interaction of straw on soil reaction when the soil carries various calcium-magnesium ratios and a common level of 0.2%, by weight, of sodium. Here, salts were added in the nitrate form. The highest acidity measured was in the treatment where no calcium or magnesium was added—i.e., 0/0. Two months after the addition of straw the acidity was 27.87 $\times 10^{-6}$ gram of hydrogen ion (pH 4.56) even in the presence of 0.2% of sodium. However, as straw decomposition subsided the acidity was reduced significantly to 8.62 $\times 10^{-6}$ gram of hydrogen ion (pH 5.07) by the third month. In those treatments where calcium and magnesium were present there was an increase in acidity at 2 months as the calcium-magnesium ratios narrowed from 4/1 and 1/4 down to 1/1. At 3 months these values fell off as the acid-producing processes reduced in activity.

Acid Production

Interpretation of the data in this problem is difficult because of the complexity of the system under study. For example, in Table IV, the hydrogen ion value 2 months after addition of straw to the 0/0 treatment was 27.87 $\times 10^{-6}$ gram (pH 4.56). This relatively high acidity may be attributed to the following factors: formation of free nitric acid, formation of organic acids as a result of the straw decomposition, and ultimate formation of carbonic acid, the carbon dioxide being derived from the straw breakdown. Continuing with Table IV, the hydrogen ion values for the other calcium-magnesium ratios 2 months after the addition of straw are considerably lower than that for the 0/0 treatment. Straw decomposition and acid production may be just as rapid as in the 0/0 treatment, but the presence of the calcium and magnesium in varying amounts tends to modify the soluble acidity, which is reflected in the measurement of the hydrogen ion values.

Utilization of crop residues is a recognized soil conservation practice. In areas where 2 to 3 tons or more of straw are worked into the soil the acidity will increase significantly unless there are sufficient basic constituents in the soil to neutralize the acidity produced. This temporary increased acidity may influence the growth of crops by reducing the availability of certain plant nutrients.

Summary

Addition of straw at a rate of 1 ton

Table IV. Effect of Straw[a], Calcium Nitrate and Magnesium Nitrate Treatments on H Ion Concentration[b] of Sodium-Soil

Sample	Calcium-Magnesium Ratios					
	0/0	4/1	2/1	1/1	1/2	1/4
Before adding straw	0.20 (6.70)	0.15 (6.82)	0.23 (6.64)	0.23 (6.64)	0.25 (6.60)	0.12 (6.92)
2 mo. after adding straw	27.87 (4.56)	0.01 (8.00)	2.11 (5.68)	6.86 (5.16)	6.22 (5.21)	0.10 (7.00)
3 mo. after adding straw	8.62 (5.07)	0.01 (8.00)	0.41 (6.39)	1.37 (5.86)	1.75 (5.26)	0.04 (7.40)
L.S.D. for interaction		(0.01) = 2.85;		(0.05) = 2.13		

[a] Straw added at rate of 1 ton per acre.
[b] Mean values shown for H ion concentration to be considered as "mean $\times 10^{-6}$ gram H ion"; pH values are given in parentheses.

per acre increased the soil acidity very significantly for at least the duration of the experiment, which was 3 months.

Before the addition of straw, soils containing the nitrates of calcium and magnesium were slightly more acid than those containing the carbonates of calcium and magnesium. After the addition of straw, the acidity in the soil treated with the nitrates increased very significantly over the soil treated with carbonates, even though nitrogen levels in all treatments were equivalent.

Sodium nitrate in the calcium and magnesium nitrate treatments exerted a significant effect in counteracting acidity between 2 and 3 months after straw addition. However, where calcium and magnesium were not present, sodium nitrate and straw resulted in more soil acidity than straw alone.

Literature Cited

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Received for review February 2, 1953. Accepted April 10, 1953. Published with the approval of the director of the Idaho Agricultural Experiment Station as Research Paper 357.

PLANT NUTRIENTS

Foliar Applications to Vegetable Crops

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Urea spray with a suitable wetting agent applied to the foliage in the regular spray program for control of insects and disease has proved very effective in supplying nitrogen to certain vegetable crops. Urea and ammonium nitrate in equal mixture can be used for certain vegetable crops at a greater concentration than either material alone.

THE UTILIZATION OF NUTRIENTS through the leaves of plants has been investigated by a number of workers (*2, 3, 5, 6, 8*). For several years it has been known (*1, 4, 7*) that such deficiencies as iron and manganese can be corrected through foliage application of these elements. Compounds like urea and ammonium nitrate are rather effective in supplying a readily available source of nitrogen for the plants, particularly where plants are often sprayed or have a low nitrogen-consumption capacity. The object of this presentation is to explain the experiences of the authors with foliar sprays.

Variability of Tolerance of Plants

Tomatoes will tolerate only between 4 and 5 pounds of urea per 100 gallons of water when used as a spray material at the rate of 150 gallons per acre. The recommended pest-control spray program for tomatoes consists of five to seven sprays of insecticides and fungicides per crop, applied at the rate of 150 gallons per acre. It, therefore, becomes obvious that a moderate amount of nitrogen can be applied as urea spray as part of the regular spray program. It has been the experience of the authors that urea is compatible with the fungicides and insecticides ordinarily applied.

Ten sprays of urea at weekly intervals plus 1500 pounds of an 0–10–10 (N–P_2O_5–K_2O) fertilizer mixture as compared to 1500 pounds of a 5–10–10 alone produced nearly comparable yields. This work was continued for a 2-year period and then the better program seemed to be to apply part of the nitrogen in a 3–10–10 (or 3–12–12) fertilizer mixture and the balance as a spray. Table I shows comparable results with the urea spray as the source of nitrogen.

In carrot production, however, the situation is different. Up to 30 pounds of urea per 100 gallons of water can be used effectively, but the suggested rate is 20 pounds per 100 gallons. If this procedure is combined with the three or four sprays normally applied to control diseases and insects, a considerable portion of the nitrogen used by carrots can be supplied.

The original experiments with carrots were designed to supply all of the nitrogen from urea spray, in which case a ton of 0–10–10 fertilizer was applied broadcast previous to planting. Later experiments indicated that it was desirable to apply part of the nitrogen as commercial fertilizer, using a 3–10–10 or a similar grade and supplementing with the urea spray (Table II).

So far no chemical reaction of the urea spray with the insecticides and fungicides normally used with tomatoes and carrots has been observed.

Urea and Ammonium Nitrate Mixture

Experimentation was started with the use of urea and ammonium nitrate combination sprays. It was found that more nitrogen could be applied without injury using this combination than using urea or ammonium nitrate alone. In fact, the application of nitrogen in the form of spray could be doubled in almost all cases. However, ammonium nitrate could not be used with arsenicals unless lime was included in the mixture.

It is the practice of a number of growers, particularly in southern New Jersey, to use calcium arsenate at the recommended rates of 4 to 6 pounds per 100 gallons of water without lime. Under these circumstances ammonium nitrate appeared to increase the solubility of the arsenate to such an extent as to cause toxicity. Therefore, it is undesirable to use ammonium nitrate without lime in the spray mixture. On the