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Effects of Urea and Some Other Nitrogen Compounds on Germination of Wheat

Walter R. Zich

EFFECTS OF UREA AND SOME OTHER NITROGEN COMPOUNDS ON GERMINATION OF WHEAT

By

Walter R. Zich

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EFFECTS OF UREA AND SOME OTHER NITROGEN COMPOUNDS

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department

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INTRODUCTION

The use of commercial fertilizers has become an accepted practice in American agriculture. About two-thirds of the total amount sold in the United States may be classed as mixed fertilizer. The remaining one-third consists of fertilizers containing only one of the three plant nutrients--nitrogen, phosphorus or potassium.

Among nitrogenous fertilizers, urea possesses characteristics which make it suitable for use in mixed goods and desirable for direct application to soils requiring only nitrogen. Urea is a concentrated fertilizer usually containing about 45% nitrogen. This high proportion of nitrogen is higher than for any other commercial solid nitrogenous fertilizer material. Often urea is cheaper than other forms of nitrogen per pound of plant food when transportation is an appreciable part of the total fertilizer cost.

Although urea may appear to be an ideal nitrogen carrier, it has been credited with reducing germination of various crop seeds when applied at time of planting. This damage to stands has been observed in South Dakota under varying conditions and in different soils. Fertilization with urea has been known to cause poor germination in soils of a pH range from 6.0 to 7.8.

Reductions in both stand and yield of winter wheat in Gregory, Tripp, Lyman and Stanley counties in South Dakota have been reported by Puhr et al (13).

In Fall River County, South Dakota, in 1955, corn research plots treated with 120 pounds of nitrogen per acre as urea, tilled, planted and irrigated immediately resulted in a severe reduction in stand. When ten inches high this corn still appeared to be affected by the urea treatment.

The objective of this study was to observe the effect of urea on germinating wheat and attempt to determine what specific agent or condition causes poor seed germination when urea is applied as fertilizer. Germination trials were conducted under low temperature conditions and in the field. Laboratory measurements included conductivity, pH, nitrites and ammonia.

REVIEW OF LITERATURE

Although urea is water soluble, Collings (4) stated that very little of it is utilized in this form by common field crops. He further postulated that it is converted to ammonia and nitrates and absorbed by plants in these forms. In addition, there was mention of damage to germinating seeds because of bacterial conversion of urea to carbamide urea. Another reaction product of urea fertilization listed was ammonium carbonate. Waksman (18) listed ammonia, carbon dioxide and water as products of urea hydrolysis and ammonium carbonate as an intermediate.

When fertilizers are placed directly in contact with germinating seeds in the soil, it is often difficult for these seeds to imbibe water because of an increased osmotic effect due to the fertilizer salts. Olson and Dreier (10) investigating fertilizer placement in Nebraska noted the harmful effect of urea on crop stands. They stated that "... urea was not the least harmful as would be expected if only a total salt phenomenon were involved." A greater soil organism activity due to urea was suggested as the cause of the damage.

Kidd, as reported by Curtis and Clark (5), observed that low temperatures and low oxygen concentrations combined with high carbon dioxide concentrations prevented germination. Collings (4) and Waksman (18) listed carbon dioxide as a product of urea hydrolysis.

When the temperature of stockpiled urea increases to a critical point, some of it is converted to biuret and free ammonia. According to Hardesty (8) this reaction occurs at temperatures of 133° C. or higher. Biuret exists as an impurity in many commercial brands of fertilizer urea.

Starostka and Clark (16) found a significant reduction in yield of perennial ryegrass in pots when fertilized with 30 pounds of nitrogen per acre as biuret. However, other pots growing corn and oats and fertilized with 100 pounds of nitrogen per acre as urea-biuret mixtures produced no significant differences among treatments. The proportion of biuret in the mixtures ranged from zero to ten percent. Rai et al (14) investigated the effect of biuret, C.P. urea and commercial urea on bean plants grown on different soil types. The treatments were applied at rates of 10, 20 and 40 pounds of nitrogen per acre. Biuret was found to be toxic to plants but the urea did not cause a yield depression. Bean growth was retarded more by biuret on clay soil than on sandy soil. The greatest growth was on muck soil.

The differences observed in the effects of urea and biuret on plant growth may be partially accounted for by the changes they undergo before assimilation by plants. Urease is the enzyme that will catalyze urea hydrolysis. According to Tauber (17) urease is absolutely specific and acts only on urea. The enzyme necessary for biuret breakdown is not known at the present time. Porter (11) found that of 12 species of bacteria that could utilize urea only seven used biuret. Urea and biuret may differ appreciably in the changes and effects they produce in soils.

As early as 1931 Willis and Piland (20) recognized the injurious effect of free ammonia on seedlings. They stated that if carbon dioxide were also present, the product formed would be ammonium carbonate, which is also detrimental to seedlings. These investigators related the use of calcium sulfate and calcium carbonate to supplement ammonium hydroxide and reduce injury to seedling cotton. Olson and Dreier (10) advocated separation of placement zones of ammonia and seed if seeding and fertilization were done simultaneously. Waksman (18) stated that free ammonia was injurious to growth of nitrate bacteria and that this was due to penetration of the base into the cell. According to Chapman and Liebig (3) ammonia injured nitrate-producing bacteria.

Bingham et al (2) found that tomatoes tolerated very little nitrite-nitrogen in an alkaline solution. Based on dry soil weight, ten parts per million or more of nitrite in the root zone could be toxic. However, they stated further that these concentrations were not likely to occur with normal fertilizer usage but only with heavy applications of urea or anhydrous ammonia. Heavy dosages or band applications could result in growth depression because of nitrite accumulation. A study by Chapman and Liebig (3) disclosed that urea or anhydrous ammonia added to neutral or alkaline soils in sufficient quantity may cause nitrites to accumulate. Nitrites have not been found to accumulate in acid soils under these conditions.

According to Russell (15) nitrites may accumulate in soils at a high pH because of a lower phosphorus requirement of nitrite-producing than nitrate-producing bacteria. The pH at which this occurs may correspond to the pH which is critical in phosphorus uptake by plants from the soil. This comparison has been proposed by Martin et al (9) who found pH 7.7 to be a threshold value for the nitrification of ammonia in desert soils. They also mentioned that nitrate forming bacteria may lack phosphorus. Above pH 7.7 nitrites were found to accumulate but nitrates were lacking in well-aerated soils under favorable conditions of temperature and moisture. Nitrites decreased to trace quantities almost immediately after nitrates began to form. Duisberg and Buehrer (6) applied ammonia to a fine sandy loam with an initial pH of 7.8 and increased alkalinity. Injecting ammonia into the soil raised the pH to 9.2, and spraying the soil with an ammonia solution increased the pH to 8.6, while irrigating with ammonia added to the irrigation water resulted in raising the pH to 9.5. Within eight days the pH in all cases was down to 7.4. A nitrite accumulation of 60 to 80 parts per million occurred after seven to twelve days but the pH had dropped to 7.4 by then.

Frederick (7) investigating the formation of nitrate from ammonia in soils stated that nitrification increased with temperature and pH (up to 7.7). Anderson and Purvis (1) noted a greater rise in pH after treating a sandy loam with ammonium hydroxide when the temperature was 37 degrees than when 52 degrees Fahrenheit. The initial pH was 4.9 and rose to 5.7 at the low temperature and to 5.3 at the high temperature. Russell (15) has stated the range of temperature for nitrification to be from four to 40 degrees Centigrade with 30 degrees being optimum.

In a search for the agent involved in reduced germination Duisberg and Buehrer (6) were able to germinate barley with up to 450 parts per million of ammonia. They were unable to detect the presence of any hydroxylamine or hyponitrous acid that they suspected might be formed from ammonia.

MATERIAL AND METHODS

To investigate this problem it was considered best to tabulate the proportion of planted seeds germinating rather than use grain or total plant material yields because tillering often compensates to some extent for poor stands.

Rushmore spring wheat was used for spring plantings and indoor germination trials and Minter winter wheat was planted in the fall. Seed was sorted manually before counting and only undamaged kernels were used. Ceresan (5% ethyl mercury phosphate) was used as seed disinfectant.

Soil available in bins at the Agronomy greenhouse was used for coldroom germination tests. Table 1 lists the soils used in other trials with their location and characteristics.

Table 1. Location and Characteristics of Soils Used in This Study.

No.	Location	Saturation Percent	pH	Cond.*	Soil Type
1	Brookings	50	6.9	0.9	Lamoure silty clay loam
2	Redfield	45	6.0	0.5	Beotia silt loam
3	Newell	49	7.8	0.6	Pierre clay
4	Brookings (Laboratory)	54	7.1	0.4	Fordville loam

* Conductivity of saturation extract in millimhos per cm^3 as measured with a Solu-Bridge soil tester.

Controlled Temperature Germination Trial

This phase of the study was an attempt to determine the effect of carbon dioxide, biuret and urea on seed germination at a constant temperature of 45 degrees Fahrenheit.

Ten wheat seeds were planted in each wax cup which measured three and one-fourth inches in diameter at the soil surface. Treatments made before planting were 80 and 160 pounds of nitrogen per acre of reagent grade urea; these same rates of a urea-biuret mixture consisting of 20 percent biuret; two carbon dioxide evolving treatments and a check. The carbon dioxide evolving mixture consisted of sodium bicarbonate and a chemically equivalent amount of acid potassium tartrate, with kaolin to reduce intimate contact of the two and serve as a diluent. This mixture was applied on two treatments at rates computed to evolve carbon dioxide in amounts equivalent to the two levels of urea. Treatments were applied about one-fourth inch below seed. These seven treatments were used in four replications and the wax cups were left uncovered. This entire experiment was duplicated with the cups covered by small squares of Presdwood[1]. Soil in each cup was brought to approximate field capacity by an addition of 80 milliliters of water immediately after treatment and planting. No other water was supplied. Germination counts were made on the fifteenth day after planting.

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1 One-fourth inch thick wood fiber building material.

Field Germination Trials, 1956

The sites chosen for these three trials were on the Morris estate at Brookings, the Redfield Development Farm at Redfield and the farm of Joe Harvey, Newell, South Dakota. Except for differences in dates, soil and factors associated with climate the experiments were identical.

It was hoped that differences in texture, pH, and moisture could be introduced by using soils of varied location. Treatments were included to show the effects of urea with two levels of biuret and also that of adding calcium carbonate to the soil with fertilizer.

There were four replications of eight treatments each. Treatment one was a check. Treatments two, three and four were crystal urea containing 0.15 percent biuret and applied at rates of 40, 80 and 160 pounds of nitrogen per acre. These same levels of nitrogen were repeated in treatments five, six and seven but urea used in these was 12.50 percent biuret. Treatment eight had 3000 pounds of calcium carbonate per acre applied in contact with 160 pounds of low-biuret crystal urea per acre. A randomized block design was employed and plots were six inches wide and 50 inches long. Treatments were placed manually two inches deep, covered with one-half inch of soil followed by planting of fifty seeds of spring wheat directly on this, at a spacing of one inch in the row. The remaining soil was replaced and compacted.

The dates of planting were April 20 at Redfield, April 24 at Brookings and May 12 at Newell. At all three sites the emerged plants were counted on the 27th day after planting.

A planting was made on September 26, 1956 to test the effect of urea and ammonium compounds on winter wheat. Ammonium hydroxide, containing 14 percent ammonia, reagent grade ammonium sulfate and urea were treatments. Ammonium sulfate was applied at the rate of 80 pounds of nitrogen per acre but reagent grade urea and ammonium hydroxide were applied at 40 and 80 pounds of nitrogen per acre. The sixth treatment was a check. Ammonium hydroxide was very difficult to apply uniformly. There were four replications. As the treatments were applied in contact with the seed, the 160 pound rate was not used. Due to extremely dry conditions the plot area was irrigated four days prior to treatment and planting. Design of experiment, size of plots and number of seeds planted per plot were the same as for spring wheat. Plants emerging were counted 21 days after plots were planted.

The final field planting was made on April 24, 1957. Two replications were used and three treatments included a check and 160 pounds per acre of nitrogen as urea containing 12.50 percent biuret and the same rate of urea having only 0.15 percent biuret. Plots were two feet wide and four feet long. Treatments were applied broadcast and incorporated with the surface two to three inches of soil. Fifty seeds of spring wheat were planted in drill, lengthwise, equidistant from the sides of the plot.

Laboratory Studies

To determine to what extent urea may increase soil pH, 36 wax cups of urea-treated soils were incubated at a laboratory temperature of approximately 25 degrees Centigrade and successive pH measurements made with a Coleman pH meter. Reagent grade urea was dissolved in distilled water in three concentrations and 25 milliliters of the appropriate solution applied to each cup to effect application rates of 0.01, 0.1 and 1.0 percent urea while also raising soil moisture to about field capacity. A check treatment had the same amount of distilled water applied. No more water was added during the experiment but cups were kept covered with a towel to reduce evaporation. Twenty wheat seeds were planted in one cup of each treatment to roughly establish at which level urea was toxic to germinating seeds. Measurements of pH were made after soil pastes were allowed one-half hour for equilibration.

Germination tests in the laboratory were conducted in Petri dishes. Twenty wheat seeds were wrapped in paper toweling, thoroughly saturated with water, drained and placed in each dish. The treatment, in a watchglass, was placed adjacent to but not in contact with paper. There were no replications, as the objective was to demonstrate the effect of gaseous ammonia in a system not confounded by soil. Treatments employed were a check, four levels of urea with urease and water, and 0.8 milliliter of dilute ammonium hydroxide calculated to yield the same amount of ammonia as 0.10 grams of urea.

Tests of soil pH, amount of nitrite and ammonia in treated and untreated soils were made in conjunction with the germination trial planted on April 24, 1957. A Coleman pH meter was used to measure pH and determinations for nitrite were made by the method of Prince (12) as modified for the Evelyn colorimeter by Whitehead (19). To absorb any free ammonia that may have been present, one 150 milliliter glass jar containing 100 milliliters of saturated boric acid solution was placed in each plot. These jars were embedded in soil with open tops just slightly above ground level. Treated soil was disturbed as little as possible. Inverted wax cups covered the boric acid containers. Approximate soil area enclosed as the difference between jar and wax cup diameters was 30 square centimeters. The boric acid-ammonia complex was titrated with standard sulfuric acid or sodium hydroxide as required to reach methyl purple end point. A boric acid blank was used for comparison. Titration with acid was required to bring solutions which had absorbed considerable ammonia to the methyl purple end point, whereas titration with sodium hydroxide was necessary for solutions in which no ammonia had been absorbed.

EXPERIMENTAL RESULTS AND DISCUSSION

Controlled Temperature Germination Trial

Excellent germination was obtained in this trial as only one seed of the 560 that were planted failed to grow. The particular cup in which this occurred was treated with biuret-containing urea at the rate of 160 pounds per acre. Growth of all seedlings in this cup was noticeably less than in some other cups. Generally, sprouts were from one-fourth to one inch in length with those in the covered cups being longer than those which were not covered. Soil in open containers apparently dried more than soil in those cups that were covered. In some cases this drying caused the crusted surface layer of soil to be raised perceptibly by the germinating seeds underneath. The addition of water after treatment may have dissolved and carried the urea down and away from the seeds, thus causing the effect of treatments to be reduced.

Field Germination Trials of Spring Wheat at Brookings, Redfield and Newell, South Dakota in 1956

The percent germination of all treatments is presented in Figure 1 as the mean of four replications.

Increased amounts of urea or biuret in urea adversely affected seed germination. Addition of calcium carbonate to the 160 pound rate of low-biuret urea noticeably improved germination at Brookings and Redfield but increased it only slightly at Newell. It is quite likely that some calcium carbonate inherent in Pierre clay, annulled the effect of adding it as a treatment at Newell.

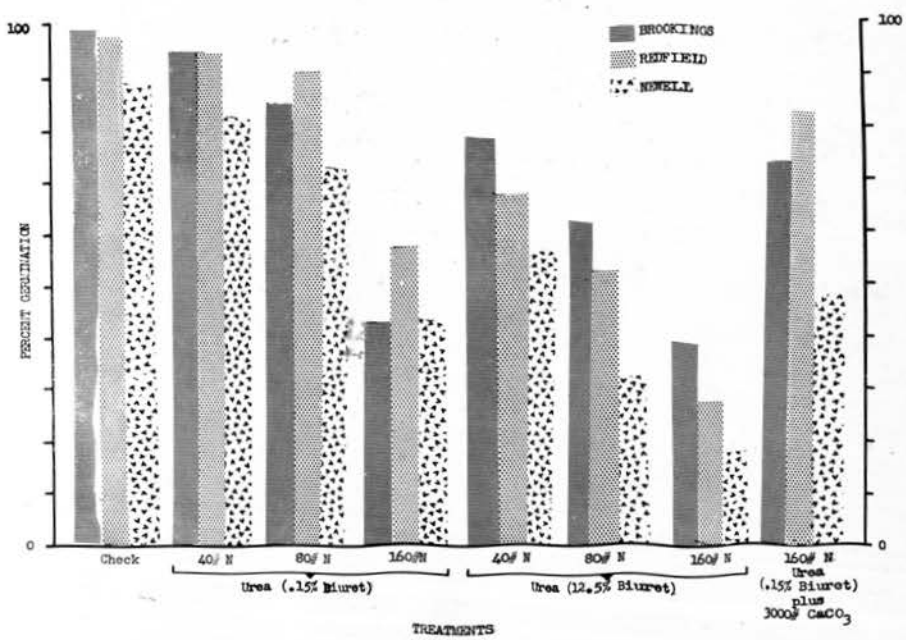

Figure 1. Effect of eight treatments on germination of spring wheat at Brookings, Redfield and Newell, 1956.

Figures 2 and 3 show one replication of the field germination trials of spring wheat at Brookings.

The mean germination percent of all treatments at each of the three locations was Brookings, 72.06; Redfield, 71.38 and Newell, 55.19. This low figure for Newell occurred despite a half-inch rain immediately after planting of plots. If damage of urea to stands is affected by temperature and rate of nitrification, poorer germination at Newell may be explained in part by the 18-day difference in planting dates.

Analysis of variance of data obtained at the three sites is presented in Tables 2, 3, and 4. Because of the large mean square values obtained for treatments at all locations, treatment variance was divided to correspond to individual degrees of freedom.

All components of treatment variance were significant at the one percent point at Redfield but Brookings and Newell sites provided exceptions. In these latter cases 80 vs. 160# N (High Biuret) is significant only at the five percent level. Addition of calcium carbonate as a treatment at Brookings was significant only at the five percent point. The lack of significant differences when calcium carbonate was added at Newell has been discussed.

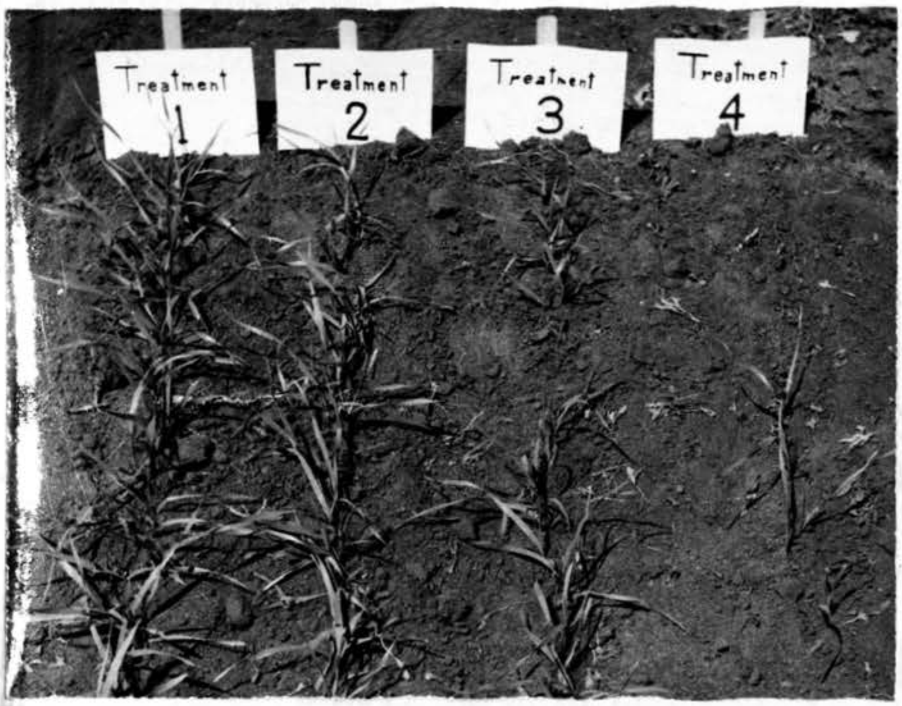

Figure 2. Field germination trials of spring wheat at Brookings.

1. Check
2. 40# N as Urea (Low Biuret)
3. 80# N as Urea (Low Biuret)
4. 160# N as Urea (Low Biuret)

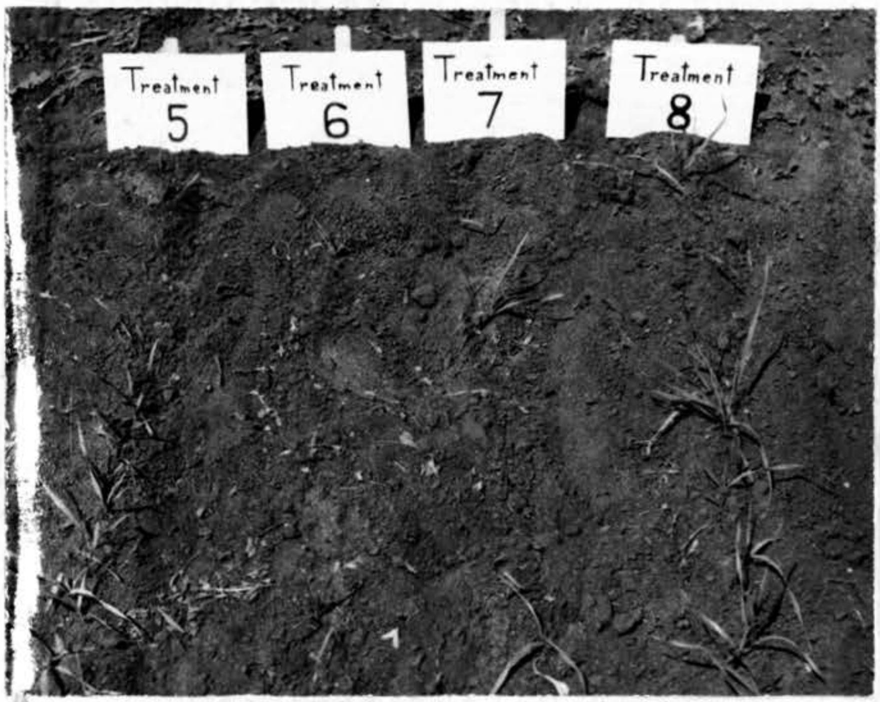

Figure 3. Field germination trials of spring wheat at Brookings.

5. 40# N as Urea (High Biuret)
6. 80# N as Urea (High Biuret)
7. 160# N as Urea (High Biuret)
8. 160# N as Urea (Low Biuret) plus 3000# $CaCO_3$

Table 2. Analysis of Variance in Data Obtained from Field Germination of Spring Wheat at Brookings.

Source of Variation	D.F.	M.S.
Treatments	7	1164.5**
Replications	3	108.5 N. S.
Error	21	85.9
Total	31	
Components of Treatment Variance		
Check vs. Treatments	1	2770.8**
Low vs. High Biuret	1	900.5**
40 vs. 80 and 160# N (High Biuret)	1	760.4**
80 vs. 160# N (High Biuret)	1	409.4*
40 vs. 80 and 160# N (Low Biuret)	1	1525.2**
80 vs. 160# N (Low Biuret)	1	1143.0**
$CaCO_3$ vs. No $CaCO_3$ (Low Biuret)	1	642.1*
Total	7	

* Significant at 5% level.
** Significant at 1% level.
N.S. Not Significant.

Table 3. Analysis of Variance in Data Obtained from Field Germination of Spring Wheat at Redfield.

Source of Variation	D.F.	M.S.
Treatments	7	1349.4**
Replications	3	311.6*
Error	21	64.6
Total	31	
Components of Treatment Variance		
Check vs. Treatments	1	2571.0**
Low vs. High Biuret	1	2921.7**
40 vs. 80 and 160# N (High Biuret)	1	797.6**
80 vs. 160# N (High Biuret)	1	562.5**
40 vs. 80 and 160# N (Low Biuret)	1	851.8**
80 vs. 160# N (Low Biuret)	1	865.2**
$CaCO_3$ vs. No $CaCO_3$ (Low Biuret)	1	876.1**
Total	7	

* Significant at 5% level.
** Significant at 1% level.

Table 4. Analysis of Variance in Data Obtained from Field Germination of Spring Wheat at Newell.

Source of Variation	D.F.	M.S.
Treatments	7	1007.6**
Replications	3	7.2 N.S.
Error	21	29.8
Total	31	
Components of Treatment Variance		
Check vs. Treatments	1	2278.4**
Low vs. High Biuret	1	1916.9**
40 vs. 80 and 160# N (High Biuret)	1	981.6**
80 vs. 160# N (High Biuret)	1	186.0*
40 vs. 80 and 160# N (Low Biuret)	1	984.1**
80 vs. 160# N (Low Biuret)	1	692.6**
$CaCO_3$ vs. No $CaCO_3$ (Low Biuret)	1	13.9 N.S.
Total	7	

* Significant at 5% level.
** Significant at 1% level.
N.S. Not Significant.

Effect of Urea, Ammonium Hydroxide and Ammonium Sulfate on Field Germination of Winter Wheat at Brookings in 1956

The results of the germination trials are presented in Table 5.

Table 5. Effect of Various Nitrogen Sources on Field Germination of Winter Wheat at Brookings, 1956.

Treatments	Percent Germination
Check	78.00
40# N as Urea	67.50
80# N as Urea	42.50
40# N as Ammonium Hydroxide	56.00
80# N as Ammonium Hydroxide	48.00
80# N as Ammonium Sulfate	72.00

Least significant difference at 5% level = 1.8 percent.

These data indicate that urea and ammonium hydroxide have a comparable effect on germination of winter wheat while ammonium sulfate does not appear to be as detrimental to stands. The reversal of position of urea and ammonium hydroxide applied at 40 pounds with the same treatments at 80 pounds in their effect on germination may be due to differences in ammonia release. Urea may be expected to release ammonia over a longer period of time than ammonium hydroxide.

The analysis of variance is presented in Table 6. Part of the variance due to replication was apparently caused by the detrimental effect of irrigation and tillage on structure.

Table 6. Analysis of Variance in Winter Wheat Data, Brookings, 1956.

Source of Variation	D.F.	M.S.
Treatments	5	296.4**
Replications	3	172.1**
Error	15	25.8
Total	23	

** Significant at 1% level.

Petri Dish Germination Tests

All rates of urea exceeding and including 0.02 grams of urea per dish completely prevented any wheat seeds from germinating. This was also true for the dish containing ammonium hydroxide. Out of 20 seeds, two germinated well and five poorly when placed in a dish with 0.01 grams of urea, urease and a small amount of water. In an untreated check, 16 seeds germinated. After six days the urea treatments smelled more strongly of ammonia than the dish treated with ammonium hydroxide. The effect was obviously transmitted as a gas. Ammonia may also be evolved in biuret hydrolysis. Petri dishes and their contents were not sterilized.

Soil-Urea pH Changes

Figure 4 demonstrates the pH changes occurring in soils treated with urea at various rates. Germination results of the treatments were as follows: soil with no urea germinated 95 percent; 0.01% urea, 100 percent; 0.10% urea, 95 percent and with 1.00% urea none of the seeds germinated.

Although 0.10% urea is equivalent to 1000 pounds of urea per acre when incorporated with three inches of soil, this concentration is easily exceeded locally when urea is applied in bands.

Soil treated with 1.00% urea became very sticky when made into a paste for pH measurement. This condition caused difficulty in washing the soil from electrodes and out of cups.

Effect of Urea and Biuret on Spring Wheat Germination, pH, Nitrite and Free Ammonia in Soil

Graphs depicting the results obtained in this experiment are shown in Figure 5. The treatments listed are rates per acre (area basis). Data presented are the means of two replications.

The high biuret rate was furnished by commercial fertilizer urea containing 12.50% biuret and the low biuret rate by crystal urea containing 0.15% biuret.

Soils of treatments 2 and 3 had a higher pH and nitrite content and resulted in poorer germination than treatment 1. Amount of ammonia was less in unfertilized plots. The relative ammonia values are not closely correlated with germination percentages nor did it appear that nitrite or pH differences could cause this reduction in germination. Considerable difficulty was experienced in getting soil extracts suitable for nitrite testing. Lack of adequate sampling and heterogeneity of soil may account for discrepancies in these data.

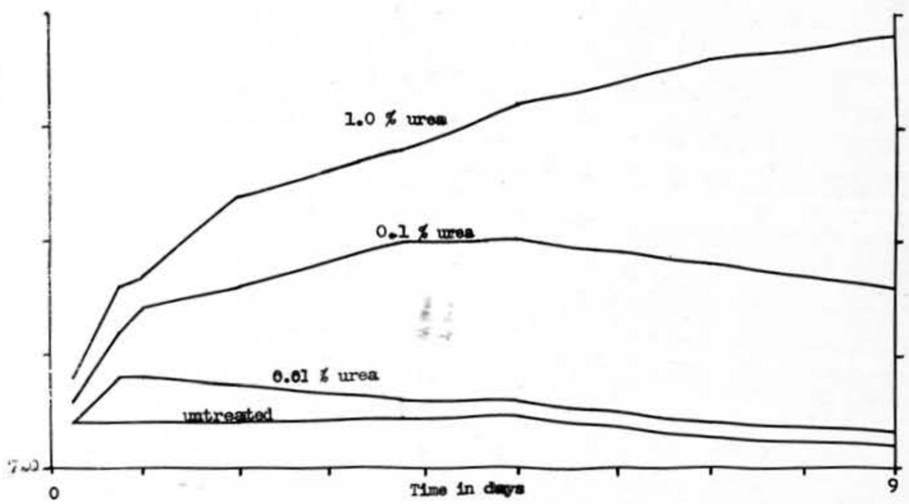

Figure 4. Effect of urea on pH of Fordville loam.

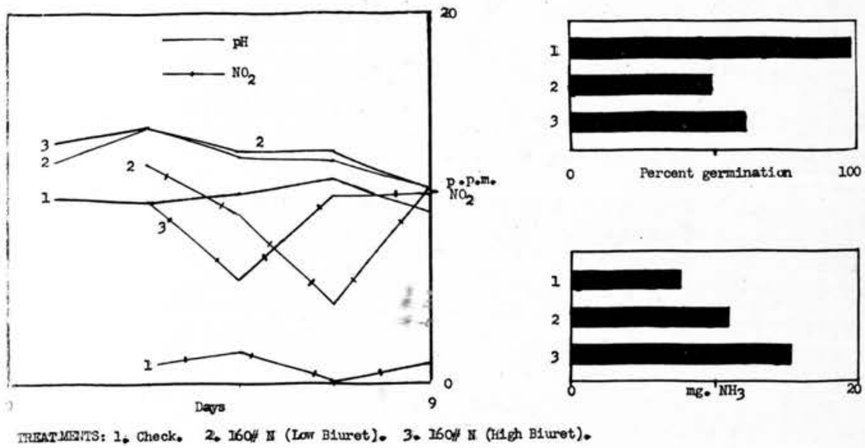

Figure 5. Effect of urea and biuret on soil pH, nitrite and ammonia content, and on germination of spring wheat.

SUMMARY AND CONCLUSIONS

Various experiments were conducted in the field, in controlled temperature rooms and laboratories to observe the effect of urea on germination of wheat and attempt to ascertain the agent or condition causing this effect.

Treatments applied in field germination trials were urea, urea-biuret mixtures, calcium carbonate, ammonium hydroxide and ammonium sulfate. Urea, a urea-biuret mixture and a carbon dioxide evolving treatment were used in controlled temperature germination tests. Laboratory measurements utilized urea, urease, ammonium hydroxide and reagents associated with pH, ammonia and nitrite determinations.

At a constant temperature of 45 degrees Fahrenheit carbon dioxide either from urea or other sources did not inhibit germination. At higher temperatures its effect is probably less.

Urea containing 12.50% biuret significantly decreased germination of wheat in the field when compared to urea containing only 0.15% biuret. This was not true in all instances, however. Urea having only minute amounts of biuret or reagent grade urea also reduced germination of wheat. The deleterious effect of urea and biuret appeared to increase, within limits, as temperature increased. This may coincide with greater soil microorganism activity and increased ammonification rates.

Ammonia was found to be present in the soil to a greater extent where urea was applied than where it was not applied. In Petri dish cultures one-tenth gram of urea with urease and water or an equivalent (NH_3 basis) amount of ammonium hydroxide completely prevented germination of wheat and indicated transfer of effect by a gas. Nitrogen compounds which yield ammonia such as urea (biuret) and ammonium hydroxide caused considerable reduction of germination. This was not true of equivalent applications of ammonium sulfate. Quite possibly ammonia occurred in the soil also as ammonium hydroxide or ammonium carbonate. Both compounds are volatile and either one could increase pH.

Adding urea to soil increased pH both in the laboratory and in the field. The maximum pH attainable is probably dependent on initial pH and associated soil characteristics.

Although small nitrite increases attended urea and biuret treatments and higher pH values, the concentration required for toxic effect was not established in this study.

It is concluded on the basis of these results that the major deleterious effects of urea on germination are the high pH and high concentration of ammonia engendered near the seed as a result of hydrolysis and other changes which urea and biuret undergo. Further work should be done to determine the concentration tolerance of various agronomic crop seeds to both ammonia and high pH values.

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