UREA AS A SOURCE OF NITROGEN FOR IRRIGATED WHEAT

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DEDICATION

Dedicated to my late father

Mu'azu Sa'idu

and to my mother

Halima

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

UREA AS A SOURCE OF NITROGEN FOR IRRIGATED WHEAT

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An experiment was conducted in the greenhouse to evaluate urea by comparing responses of irrigated wheat to treatments involving urea, ammonium sulfate and sulfur coated urea (SCU). Grain yield, total dry matter, 100 seed weight and grain to stover ratio were observed. The wheat was an early maturing, short statured variety (Yecora Rojo).

The study experiment was conducted on an acid loam (pH 6.5) and a calcareous clay loam (pH 7.6). The fertilizers were either surface applied or soil incorporated at rates of 0, 50, 100, and 150 lbs. N per acre. The experiment consisted of a factorial arrangement, four replications and a completely randomized block design.

There was no significant difference in wheat grain yield, total dry matter, 100 seed weight and grain to stover ratio resulting from treatments that had received either urea or ammonium sulfate or between plots that had received either urea or SCU.

Ammonium sulfate treatments produced significantly higher grain yield and total dry matter than treatments that had received SCU.

There were no significant differences in grain yield total dry matter production, 100 seed weight and grain to stover ratio between plots that had received surface application of nitrogen and those that had received soil incorporation of the same material.

CHAPTER I

INTRODUCTION

Fertilizer has played a very important role in raising the level of agricultural productivity and improving the farmer's income. Sixty percent of yield increases, particularly in the more advanced countries, is attributable to the national use of fertilizers. In many of the developing countries of Africa and Asia, fertilizer is the most important singular input and may take the largest proportion of the total farm investment. The total value of fertilizer use estimated for 1985 will represent approximately 45 percent of the total value of all current input in agricultural production in the developing countries (30). The demand for fertilizer in the latter nations is still increasing particularly with the development and adoption of new high yielding cereal varieties. Research data in the tropics have indicated plant recovery of fertilizer nitrogen ranges only between 50 to 60 percent; the remaining 40 to 50 percent may be lost from the soil through leaching and volatilization (62). Newer research findings using ^{15}N isotopes are indicating even much lower plant recoveries of soil applied nitrogen than previously estimated (54, 15, 25). Phosphorus recovery by plants has also been reported to be low, largely due to fixation in the soil.

In addition to low fertilizer efficiency, transportation (and storage) costs add considerably to the final price to the farmer, especially when the fertilizer has to be imported. These costs exceed 50 percent of the farmer's price in northern Nigeria (30).

In much of Africa, ammonium sulfate has been the 'traditional' nitrogen fertilizer. The prolonged use of ammonium sulfate as a fertilizer on a tropical soil with low cation exchange capacity and initial acid reaction has the potential of further lowering the soil pH. This has been observed in some places. The drive to use a nitrogen carrier with less acid equivalent than ammonium sulfate and the need to decrease the per unit nutrient cost of nitrogen fertilizer is leading to the replacement of the latter with urea (30, 62, Table A-5).

Loss of ammonia by volatilization is to a large extent responsible for low efficiency of urea and ammonium sulfate (including other ammonium fertilizers). The volatilization process depends on the alkalinity of the soil medium. Loss of ammonia by volatilization from ammonium sulfate is generally not a problem on acid soils. Urea, however, may alter the soil pH towards alkalinity, depending on the buffering capacity of the soil, resulting with volatilization loss of ammonia.

The objective of this study is to evaluate urea by comparing it with ammonium sulfate and sulfur coated urea under varying soil conditions and fertilizer placement on the basis of grain yield, total dry matter, seed weight and grain to stover responses to the fertilizers by an irrigated wheat. The grain to stover ratio is included to show if SCU will produce excessive vegetative growth. The study will be carried out on two types of soils; a light acid soil (pH 6.5) of low buffering capacity (C.E.C. 11me/100g) and a heavier calcareous soil (pH 7.6) with medium C.E.C. (38me/100g). Two fertilizers will be applied as surface or soil incorporation.

Wheat is a new crop in Nigeria. Its significance as a crop is likely to grow with the expansion of irrigation agriculture and the nation's increasing demand for flour, hence, the choice of the crop.

CHAPTER II

LITERATURE REVIEW

Though commercial synthesis of urea was begun in 1920, it was only tried as a fertilizer after 1935 (10). Prilled urea has a tendency to cake because of its hygroscopic nature which creates storage problems. It was also corrosive to handling and equipment. As such, it was never popularly accepted as a fertilizer. Later development in fertilizer manufacturing technology has led to the development of a granular urea with virtually none of the disadvantages formerly associated with urea.

Urea has the highest analysis (46 percent) of all solid nitrogen fertilizer commercially available and has a favorable economics of manufacturing which leads to a considerable savings in production, transportation, and application costs (10). It suffers less leaching in the soil than other nitrogen fertilizers because it is weakly absorbed by the soil colloids (78, 11). Urea has less acid equivalent than ammonium sulfate and would lead less to the development of soil acidity than the latter. It also has the ease and safety of handling and application of most solid fertilizers (30, 38, 61). Granular urea has currently shown a potential as a carrier for certain pre-emergent soil incorporated herbicides (10).

Urea Nitrogen and Crop Response

Urea has shown an efficiency comparable to ammonium sulfate as a source of nitrogen to many crops, including corn (maize), wheat, and rice when properly used (9, 30, 39, 50, 68). In certain instances where responses to ammonium sulfate were better, the differences were shown to be due to the sulfur component of the latter (30, 42). Foh (39) concluded that urea could be a good source of nitrogen for paddy rice applied as a single preplant incorporation or as a split application at 252 kgs. nitrogen per hectare. A linear response to urea up to a level of 250 lb/acre was obtained on an established pasture (3). Khan and Mandal have reported similar trends in a field experiment with jute up to the levels of 120 to 150 lbs. per acre (40). Uptake of soil applied nitrogen by slash pine in the coastal plain of Florida was found to be higher from urea than from ammonium sulfate (76).

Some reports, however, do indicate lower recoveries of soil applied nitrogen and lower yield from urea than ammonium sulfate (26, 81, 82).

Problems With Urea

Definite problems have been encountered with urea by some workers. Basically, these problems are in excessive loss of urea nitrogen by volatilization of ammonia and other gases and phytotoxicity of urea when applied in high concentration or in close proximity to seed (21, 38, 49, 85). These factors are critical to the efficiency of urea as a fertilizer. In some instances urea had failed to match the efficiency of some other nitrogenous fertilizers because its application to the soil had led to excessive gaseous loss or because crops had failed to recover from early adverse effects of the fertilizer (23, 65, 82). Loss of nitrogen by ammonia volatilization following urea application to soils has been widely reported (22, 32, 42, 43, 57, 58, 60, 71, 76, 85, 89). As much as 60 percent of the applied nitrogen could be lost (30, 40).

Loss of nitrogen from the soil in the form of ammonia is a purely chemical process as when ammonia is lost from aqueous solution (83). The ammonia volatilization capacity of a system depends on its alkalinity (NH_4(aq), HCO_3^{2-}). In a laboratory study, loss of ammonia from solutions lacking alkalinity was limited, but was complete in the presence of CO_3^{2-} (83). Ammonia volatilization is a rapid process and first order reaction with a half-life of about five hours at near optimum conditions. It is expected to be severe during the first few days (83, 79). Fenn and Kissel (31) have proposed a mechanism for ammonia volatilization from calcareous soils. The major factor involved is the solubility of the potential reaction product. An insoluble calcium salt reaction product greatly favors the formation of ammonium carbonate. The latter is unstable and decomposes to release carbon dioxide and ammonia. More carbon dioxide is lost than ammonia which consequently results in the formation of ammonium hydroxide and further volatilization loss of ammonia.

Incubation studies have shown that urea applied to soils undergoes rapid hydrolysis especially under high temperatures and is essentially complete within four to six days (7, 72, 73, 74, 76).

The hydrolysis appears to follow a first order reaction with an average half-life of 3.7 to 7.9 hours (74). The rate of hydrolysis depends upon the kind of soil, the moisture level, the organic matter content and is little affected by temperature (60, 76). Hydrolysis is slower in flooded soils, in saline soils and in fine textured soils (66, 74, 76). The first product of urea hydrolysis is ammonium carbonate. The latter, according to the local concentrations and the soil's buffering capacity may temporarily render the soil alkaline (40, 59, 77, 85) and ammonia may be lost according to the mechanism already outlined.

Loss of nitrogen by ammonia volatilization is not unique to urea but may occur under certain conditions when ammonium containing fertilizers are applied to soils. Substantial gaseous losses of nitrogen was observed when ammonium sulfate was applied to some alkaline soils (2, 44, 60, 85). The cumulative loss of ammonia following surface application to the alkaline soil of the Sudan Gezira was found to be consistently higher for ammonium sulfate than urea (60). Losses were greatest during the first week and increased with higher application rates (60). Losses were found to be similar from urea and ammonium sulfate in other cases (41). Other factors affecting volatilization losses of ammonia have been studied (41, 29, 46, 87, 6, 86). Ammonia volatilization is accompanied by loss of alkalinity which tends to terminate the process. Calcium carbonate, when present, will supply the alkalinity to perpetrate the process. Fenn and Kissel (34) reported a rapid increase in the loss of ammonia with increase in soil calcium carbonate up to 6.1 percent. There was no further increase beyond a soil calcium carbonate of 9.7 percent. Thus loss of ammonia from urea and other ammonium fertilizers is much more serious following surface application to a calcareous soil. Incorporation of the fertilizer markedly reduces the loss (35, 58, 85). Increasing temperature and/or soil pH increases volatilization loss of ammonia. The effect of temperature is much more pronounced in non-calcareous soils than in calcareous soils (33, 56). Initial soil moisture affects ammonia volatilization. There is no volatilization loss of ammonia from a dry soil (29, 86). As little as one percent soil moisture is enough to start the process, but the rate of ammonium loss decreases with increasing soil moisture content (36, 38, 56). Field measurements of ammonia volatilization (44) have indicated a diurnal pattern corresponding to fluctuations in the atmospheric relative humidity. Total loss of ammonia as a percent of the applied nitrogen did not increase with increasing application rates as laboratory studies suggested, but it shows greater response to soil temperature. Volatilization loss of ammonia decreases with increasing soil cation exchange capacity (6, 36, 56).

Loss of ammonia by volatilization is not the only factor involved. There is an hypothesis that reactivity of nitrous acid in fully aerobic soils may also be involved. The important reaction involved seems to be the spontaneous decomposition of nitrous acid according to the following:-

$$4HNO_2 \rightarrow 2NO + 2NO_2 + 2H_2O$$

$$2NO + O_2 \rightarrow 2NO_2 \rightleftharpoons N_2O_4$$

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Some nitrate is being formed and the reaction follows a cyclic process. Loss of nitrogen as nitrogen dioxide from soils can thus occur. Loss of nitrogen can also occur from interaction of nitrite with soil organic matter by Van Slake's reaction. The latter involves the reaction of nitrous acid with amino groups or ammonia.

$$RNH_2 + HNO_2 \rightarrow ROH + N_2 + H_2O$$
$$NH_3 + HNO_2 \rightarrow NH_4NO_2 \rightarrow N_2 + 2H_2O$$

A number of reports have indicated nitrite accumulation in soils both under incubation and field studies (17, 42, 47, 14, 61, 71, 64, 74). Some have indicated a nitrogen deficit which could not be accounted for by the loss of ammonia or nitrification (81, 61, 47, 57). Clark, et al. (17) observed a mineral nitrogen deficit exceeding 25 percent of the applied nitrogen (urea) for poorly buffered and acid soils which accumulated nitrite during an incubation. Jones (47) noted that conversion of nitrite to nitrate was much slower in the Norfolk sand (acid) than the conversion of ammonia following urea hydrolysis to nitrite. Ayanaba and Kang (7) have also reported slow nitrification in an acid soil (pH 4.7) and a small accumulation of nitrite. The bottleneck in the nitrification of ammonia following urea hydrolysis or soil application of ammonium fertilizers appears to be the oxidation of nitrite to nitrate. This has been attributed to the toxic effect of both ammonia and nitrite ions on the nitrifying bacteria. The optimum levels of ammonium and nitrite ions for _nitrosomonas_ and _nitrobacter_ lies approximately at 0.005 N NH_4^+

and 0.0072N NO_2^-, respectively (53). Free ammonia and excess nitrite have been found to poison nitrobacter (53). Computer simulation of loss of nitrogen fertilizer through chemical decomposition of nitrite of tropical soils have indicated that up to 50 percent of the added ammonium nitrogen may be lost in an acid soil when nitrification occurs at temperatures prevailing in the humid tropics (52). The rapid hydrolysis of urea following soil application will be a significant factor.

Pasteur first recognized that hydrolysis of urea was brought about by a living organism, Torula ammoniacale. It was later found that a whole range of microbes capable of decomposing urea are also found in most families of bacteria, actinomycetes and fungi (48). It has since been found that the transformations may be catalytic in part rather than completely biological (18, 19, 20, 55). Some evidences suggest catalytic decomposition of urea may be more important than the biological (19), at least in some soils. The catalyst has been characterized as enzymec (8). The enzyme, urease, is found to be absorbed on soil colloids. Urease is highly stable and more resistant to decomposition than added laboratory urease (18, 69). Urease activity varies in soils and has been highly correlated with soil organic matter and plant growth. In general, high urease activity is exhibited by soils with high organic matter and by soils with plant covers such as sods, pastures, cover cropped and weedy area (20). Urease activity has been seen to increase following intensive cropping or high microbial activity in the soil (20, 69).

Phytotoxicity of urea has been attributed to the ammonia and nitrite following hydrolysis and nitrification, and to biuret contamination of urea. The amount of ammonia that may be produced in the soil following high application rate of urea (or when drilled with the seeds) has been known to affect germination (60, 38, 88). Young seedlings may also be drastically affected and unless they properly recover, can lead to reduction in crop yield (21). Court, et al., (21) reported nitrite accumulation of up to 24 percent of the applied nitrogen. Many reports do not indicate such excessive nitrite accumulation (74, 7), but do still indicate the potential hazard of nitrite toxicity, particularly to sensitive crops following high soil application of urea or drilling with the seeds.

Biuret is a contaminant which may be present in commercial urea. It has been shown to be phytotoxic in very small concentration (13, 81, 48). Urea containing 2.5 percent biuret was found to reduce stand of small grains by 30 percent when an equivalent of 20 pounds nitrogen/acre was drilled with the seeds (13). Wheat germination was reduced from 85 to 82 and from 74 to 72 percent in a pot trial by increasing the biuret content of urea from 0 to 2 and 4 to 8 percent, respectively (48). Apparently biuret affects germination significantly only when urea is placed in close proximity to the seeds (13, 18). Biuret content may, however, enhance phytotoxicity from NH_4^+ and NO_2^-. Both the conversion of nitrite, as well as the subsequent oxidation of the nitrite to nitrate seems to be retarded by biuret (75).

CHAPTER III

METHOD AND MATERIALS

A greenhouse experiment involving two soils, three nitrogen carriers (urea, ammonium sulfate and SCU), two methods of placement (surface application and soil incorporation) at four levels of applications (0, 50, 100 and 150 pound N/acre) was planned. The factors were combined in a factorial arrangement and the treatments were replicated four times in a completely randomized block design. One soil was a loam with pH 6.5, and a C.E.C. of 11me/100g. The second soil was a slightly calcareous clay loam with pH 7.6 and C.E.C. of 38 me/100g.

The soils were crushed into fine grains while still moist and allowed to dry. Two kilograms (4.4 pounds) of each soil was weighed into a polythene bag and place in a one gallon pot of known weight. The amount of fertilizer per pot was determined by the following expression:

$$\text{rate (gm) pot} = \frac{1.0 \times 10^{-3} \times \text{rate/acre}}{\text{percent nitrogen analysis}}$$

The fertilizer was either applied to the dry soil surface (solid) or mixed into the soil. Distilled water was "sprinkled" into each pot to bring the soil moisture to field capacity (30 percent by dry weight for the clay loam and 15 percent for the loam). The soil moisture was maintained between field capacity and -1 bar tension. The amount of distilled water needed to bring the soil to field capacity for each irrigation was determined by weight difference.

Ten seeds of the wheat variety Yecora Rojo were sown in each pot several hours after the first irrigation (12/24/78). The seedlings were thinned to three plants per pot at two weeks after sowing.

Uniform applications equivalent to 80 lbs/acre of potassium and 100 lbs/acre of phosphorous as potassium chloride and single superphosphate were made in solutions after three weeks. No additional sulfur was given. All treatments were sprayed three times with malathion beginning the first week of March to control green aphids observed on some plants. The chemical gave effective control.

The grain was ripe and dry by the end of April, but it was not harvested until May. The heads from each treatment were cut and put in a paper bag. The straw from each treatment was also cut at the soil level and put in separate paper bags. The paper bags were put in an oven at 55°C for about 48 hours to dry and were weighed separately (heads and straw). The heads were threshed in small mortars with rubber tipped pestle and the grain from each treatment separated and weighed. The grain yield, total dry matter, 100 seed weight and grain to stover ratio were used in the evaluation.

The data were subjected to a statistical analysis (ANOVA) using a computer. Comparison between treatment means was made using students' t-tests whenever necessary.

Laboratory analysis of the soil samples before the experiment and the method used is presented on Table I. All procedures are as outlined in Black (12).

CHAPTER IV

RESULTS AND DISCUSSION

Seed germination and seedling establishment were good in all treatments. Earlier seed germination was noted for treatments on the clay loam. Plant growth was generally good and all plants appeared luxurious and healthy.

Very little tillering was observed on the control treatments on the loam. Tillering was observed for all other treatments on both soils. More tillers seemed to have survived to produced some grains in the treatments receiving the 100 and 150 pounds nitrogen per acre.

Grain Yield

The data on grain yield is presented on Table 2B. The rate of fertilizer application at the 100 and 150 pound nitrogen per acre has significant influence on grain yield. This was largely as a result of increased numbers of viable heads per pot at harvest from higher amounts of tillering and tiller survival at the application rates mentioned. Similar findings were reported by other workers (80, 71, 73, 45, 62). There was no significant difference in grain yield between treatments that have received either urea or ammonium sulfate. (Table 2A) Desai and Zenda (25), working with wheat and bajra (sorghum) on a non-calcareous and a calcareous black soil, arrived at the same conclusion. Other workers have reported similar findings (1, 50, 26).

TABLE 1

Soil Chemical Characteristics

Characteristics	Clay Loam	Loam
PH (Soil Paste)	7.6	6.5
Electrical Conductivity (Saturated Extract)	0.72 mm hos/cm	---
Carbonate (Gravimetric Method)	1.4 percent	---
Cation Exchange Capacity (Sodium Saturation)	38 me/100g	11 me/100gm
Exchangeable Calcium (On Acetate Extract by Atomic Absorption)		5.8 me/100gm
Exchangeable Magnesium	2.8 me/100gm	4.0 me/100gm
Exchangeable Sodium	0.2 me/100gm	0.5 me/100gm
Exchangeable Potassium	2.0 me/100g	0.3 me/100gm
Soil Organic Matter	2.7 percent	1.1 percent
Total Nitrogen (Macro-Kjeldahl)	0.16 percent	0.08 percent
Readily Available Nitrogen (NO_3+NH_4) by Micro-Kjeldahl	14 ppm	11 ppm
$NaHCO_3$ Extractable Phosphorus	22 ppm	11 ppm
LiCL Extractable Sulfur	5.7 ppm	9.4 ppm
Available Water (Pressure Membrane)	30 percent	15 percent

TABLE 2A

Grain Yield

Fertilizer	Soil	Placement	Fertilizer Rate 0	50	100	150	Mean by Placement	Mean by Fertilizer by Soil	Mean by Fertilizer
Urea	Loam	Incorporation	0.984	0.895	1.283	1.053	1.054	1.078	1.393_{ab}*
		Surface	0.984	1.165	1.248	1.008	1.101		
	Clay Loam	Incorporation	1.489	1.593	1.880	1.563	1.631	1.708	
		Surface	1.489	2.135	1.700	1.815	1.785		
Ammonium Sulfate	Loam	Incorporation	0.984	1.230	1.448	1.853	1.379	1.284	1.478_{bc}*
		Surface	0.984	0.910	1.478	1.385	1.189		
	Clay Loam	Incorporation	1.489	1.510	1.800	1.800	1.650	1.671	
		Surface	1.489	1.783	1.660	1.835	1.692		
Sulfur-Coated Urea	Loam	Incorporation	0.984	1.075	1.103	1.133	1.074	0.999	1.283_{a}*
		Surface	0.984	0.915	0.983	0.813	0.924		
	Clay Loam	Incorporation	1.489	1.298	1.698	1.745	1.558	1.566	
		Surface	1.489	1.583	1.595	1.630	1.574		

* - Means with common letter are not significantly different.

TABLE 2B

Grain Yield, Total Dry Matter and 100 Seed Weight
by Fertilizer Application Rate

	Fertilizer	Application Rates			
		0	50	100	150
Grain Yield	Urea	1.237_a	1.447_b	1.528_{bc}	1.360_{d*}
	Ammonium Sulfate	1.237_a	1.358_{ab}	1.597_c	1.718_c
	S.C.U.	1.237_a	1.218_a	1.345_a	1.330_a
Total Dry Matter	Urea	3.218_a	3.588_b	3.851_c	3.615_{cd}
	Ammonium Sulfate	3.218_a	3.601_b	3.991_c	4.482_d
	S.C.U.	3.218_a	3.413_{ab}	3.430_{ab}	3.650_{bc}
100 Seed Weight	Urea	2.839_a	3.069_b	3.025_{ab}	2.891_a
	Ammonium Sulfate	2.839_a	2.839_a	3.004_a	3.041_a
	S.C.U.	2.839_a	2.969_{ab}	3.215_c	3.093_{bc}

* - Means with a common letter are not significantly different.

There was no significant grain yield difference between urea and sulfur coated urea. This agrees with reports by other workers (64, 23, 67, 79). Treatments receiving ammonium sulfate, however, produced significantly higher grain yield than treatments receiving sulfur coated urea.

Neither the nature of the soil nor fertilizer placement had significant effect on grain yield by fertilizer. Beri, et al (11) had noted downward movement of urea with the waterfront when surface applied to initially dry soil columns. It was very likely that the surface applied urea and ammonium sulfate may have been washed down into the soils with the first, and rather heavy irrigation.

The treatments on the clay loam gave significantly higher grain yield than treatments on the loam. This may have been due to higher initial fertility of the clay loam.

Total Dry Weight (Table 3)

Fertilizer applications rates at the 50, 100 and 150 pounds nitrogen per acre resulted with significant increase in total dry matter over the control. As with grain yield, this was largely due to tillering (80, 71, 73, 45, 62). Urea and ammonium sulfate treatments did not differ significantly in total dry matter production (1, 50).

There was no significant difference in dry matter production between treatments receiving either urea or sulfur coated urea (60, 23, 63, 74). Ammonium sulfate treatments produced significantly higher dry matter than sulfur coated urea treatments.

There was no significant interaction either between fertilizer and placement or between fertilizer and soil type.

TABLE 3

Total Dry Matter

Fertilizer	Soil	Placement	Fertilizer Rates 0	50	100	150	Mean by Placement	Mean by Fertilizer by Soil	Mean by Fertilizer
Urea	Loam	Incorporation	2.567	2.600	3.138	3.040	2.836	2.832	3.549_{ab*}
		Surface	2.567	2.843	3.010	2.888	2.827		
	Clay Loam	Incorporation	3.869	4.040	4.858	3.743	4.128	4.267	
		Surface	3.869	4.870	4.395	4.790	4.406		
Ammonium Sulfate	Loam	Incorporation	2.567	2.920	3.455	4.440	3.346	3.271	3.760_{bc*}
		Surface	2.567	2.955	3.445	3.818	3.196		
	Clay Loam	Incorporation	3.869	3.895	4.740	4.878	4346	4.376	
		Surface	3.869	4.635	4.325	4.793	4.406		
Sulfur-Coated Urea	Loam	Incorporation	2.567	2.728	2.648	3.155	2.777	2.751	3.428_{a*}
		Surface	2.567	2.663	2.865	2.805	2.725		
	Clay Loam	Incorporation	3.869	4.318	4.533	4.245	4.241	4.105	
		Surface	3.869	3.943	3.673	4.393	3.970		

* - Means with common letter are not significantly different.

Treatments on the clay loam produced significantly higher total dry matter than treatments on the loam.

100 Seed Weight (Table 4)

Nitrogen fertilization with urea, ammonium sulfate and sulfur coated urea did not produce any significant increase in the 100 seed weight over the control. This agrees with the report by Nass, et al (62) that grain weight of wheat was not significantly affected by nitrogen fertilization. Other workers (38, 45, 62) have reported a decrease in 1000 seed weight with nitrogen fertilization.

Grain to Stover Ratio (Table 5)

There was no significant difference in the grain to stover ratio between the treatments that had received urea, ammonium sulfate or sulfur coated urea. Treatments on the clay loam, however, produced significantly higher grain to stover ratio than treatments on the loam. Power and Alessi (70) have found a close correlation between the final grain yield and the nitrogen content of a tiller at the tillering stage and to the dry weight of the tiller at both tillering and heading stage. Since both the plant growth and the plant nitrogen content will be closely related to soil's available nitrogen, the higher grain to stover ratio produced on the clay loam merely reflects its higher initial fertility.

TABLE 4

100 Seed Weight

Fertilizer	Soil	Placement	Fertilizer Rate (16S/Acre) 0	50	100	150	Mean by Placement	Mean by Fertilizer by Soil	Mean by Fertilizer
Urea	Loam	Incorporation	2.917	2.850	2.850	2.875	2.858	3.054	2.995_a
		Surface	2.917	3.288	3.325	3.138	3.250		
	Clay Loam	Incorporation	2.761	2.925	3.000	2.775	2.900	2.936	
		Surface	2.761	3.213	2.925	2.775	2.971		
Ammonium Sulfate	Loam	Incorporation	2.917	2.963	3.200	3.313	3.159	3.114	3.041_a
		Surface	2.917	3.008	3.008	3.038	3.070		
	Clay Loam	Incorporation	2.761	2.813	2.413	2.950	2.725	2.967	
		Surface	2.761	3.100	3.313	3.213	2.309		
Sulfur-Coated Urea	Loam	Incorporation	2.917	3.000	2.933	3.063	2.999	3.040	3.093_a
		Surface	2.917	2.775	3.618	2.850	3.081		
	Clay Loam	Incorporation	2.761	3.113	2.975	3.188	3.092	3.146	
		Surface	2.761	2.988	3.338	3.275	3.200		

TABLE 5

Grain to Stover Ration

Fertilizer	Placement		Fertilizer Rate (16S/Acre) 0	50	100	150	Mean by Placement	Mean by Fertilizer by Soil	Mean Fertilizer
Urea	Loam	Incorporation	0.817	0.698	0.873	0.720	0.764	0.831	0.891_c
		Surface	0.817	0.965	0.995	0.730	0.897		
	Clay Loam	Incorporation	0.938	0.948	0.898	0.030	0.959	0.951	
		Surface	0.938	1.095	0.893	0.840	0.943		
Ammonium Sulfate	Loam	Incorporation	0.817	0.948	0.958	1.018	0.975	0.884	0.886_c
		Surface	0.817	0.568	1.005	0.803	0.792		
	Clay Loam	Incorporation	0.938	0.910	0.890	0.790	0.863	0.888	
		Surface	0.938	0.883	0.843	1.013	0.913		
Sulfur-Coated Urea	Loam	Incorporation	0.817	0.840	0.888	0.805	0.844	0.756	0.824_c
		Surface	0.817	0.695	0.728	0.580	0.668		
	Clay Loam	Incorporation	0.938	0.695	0.850	0.990	0.845	0.891	
		Surface	0.938	0.933	0.983	0.893	0.936		

CHAPTER V

SUMMARY AND CONCLUSION

Urea, ammonium sulfate and sulfur coated urea at rates of 150 pounds nitrogen per acre have significantly increased grain yield and the total dry matter, but not seed weight of an irrigated wheat. Urea treatment has performed as effectively as ammonium sulfate treatments both on an acid and on an alkaline, calcareous soil in terms of grain yield, total dry matter, seed weight and grain to stover ratio. Ammonium sulfate treatments, however, had produced significantly higher grain yield and total dry matter than sulfur coated urea on the same soils.

There was no significant difference in grain yield, total dry matter, seed weight or grain to stover ratio between treatments that have received surface application of nitrogen or soil incorporation of the same material.

Thus urea is as efficient as ammonium sulfate when applied as preplant soil incorporation to an irrigated wheat up to the level of 150 pound N per acre.

Urea and ammonium sulfate may be preferred over SCU in the fertilization of an early maturing, short statured wheat varieties.

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APPENDIX

TABLE A1

Analysis of Variance - Grain Yield

Source of Variation	Sum of Squares	D.F.	Mean Square	F.
Main Effects	56.682	10	5.668	37.781
Fertilizer	1.025	2	0.513	3.417*
Placement	0.044	1	0.044	0.294
Soil	14.427	1	14.427	96.158*
Rate	1.533	3	0.511	3.406*
Block	39.654	3	13.218	88.101*
2-Way Interactions	8.233	38	0.217	1.444
Fertilizer:Placement	0.093	2	0.047	0.311
Fertilizer:Soil	0.463	2	0.231	1.541
Fertilizer:Rate	1.591	6	0.265	1.767
Fertilizer:Block	1.085	6	0.181	1.206
Placement:Soil	0.495	1	0.495	3.300
Placement:Rate	0.862	3	0.287	1.915
Placement:Block	0.253	3	0.084	0.562
Soil:Rate	0.185	3	0.062	0.411
Soil:Block	1.992	3	0.664	4.427*
Rate:Block	1.213	9	0.135	0.899
Explained	64.915	48	1.352	9.014
Residual	21.454	143	0.150	
Total	86.370	191	0.452	

*Significant at 5 percent.

TABLE A2

Analysis of Variance - Total Dry Weight

Source of Variation	Sum of Squares	D.F.	Mean Squares	F.
Main Effects	149.478	10	14.948	35.178
Fertilizer	3.344	2	1.672	3.935*
Placement	0.068	1	0.068	0.160
Soil	79.503	1	79.503	187.102*
Rate	11.842	3	3.947	9.290*
Block	54.721	3	18.240	42.927*
2-Way Interactions	25.866	38	0.681	1.602
Fertilizer:Placement	0.632	2	0.316	0.744
Fertilizer:Soil	1.890	2	0.945	2.224
Fertilizer:Rate	5.377	6	0.896	2.109
Fertilizer:Block	6.042	6	1.007	2.370*
Placement:Soil	0.427	1	0.427	1.004
Placement:Rate	2.546	3	0.849	1.997
Placement:Block	0.877	3	0.292	0.688
Soil:Rate	1.388	3	0.463	1.089
Soil:Block	4.664	3	1.555	3.659
Rate:Block	2.023	9	0.225	0.529*
Explained	175.344	48	3.653	8.597
Residual	60.763	143	0.425	
Total	236.107	191	1.236	

*Significant at 5 percent.

TABLE A-3

Analysis of Variance - 100 Seed Weight

Source of Variation	Sum of Squares	D.F.	Mean Square	F.
Main Effects	14.770	10	1.477	4.716
Fertilizer	0.388	2	0.194	0.620
Placement	0.523	1	0.523	1.670
Soil	0.134	1	0.134	0.429
Rate	1.593	3	0.531	1.695
Block	12.132	3	4.044	12.912*
2-Way Interactions	16.500	38	0.434	1.386
Fertilizer:Placement	0.131	2	0.065	0.209
Fertilizer:Soil	0.890	2	0.445	1.420
Fertilizer:Rate	3.350	6	0.558	1.783
Fertilizer:Block	3.243	6	0.541	1.726
Placement:Soil	1.566	1	1.566	5.000*
Placement:Rate	1.169	3	0.390	1.244
Placement:Block	1.225	3	0.408	1.304
Soil:Rate	0.853	3	0.284	0.907
Soil:Block	1.476	3	0.492	1.571
Rate:Block	2.597	9	0.282	0.921
Explained	31.270	48	0.651	2.080
Residual	44.785	143	0.313	
Total	76.055	191	0.398	

*Significant at 5 percent.

TABLE A-4

Analysis of Variance - Grain to Stover Ratio

Source of Variation	Sum of Squares	D.F.	Mean Square	F.
Main Effects	15.823	10	1.582	25.088
Fertilizer	0.123	2	0.062	0.978
Placement	0.009	1	0.009	0.148
Soil	0.437	1	0.437	6.929*
Rate	0.087	3	0.029	0.459
Block	15.166	3	5.055	80.158*
2-Way Interactions	2.626	38	0.069	1.096
Fertilizer:Placement	0.014	2	0.007	0.111
Fertilizer:Soil	0.027	2	0.014	0.215
Fertilizer:Rate	0.196	6	0.033	0.517
Rertilizer:Block	0.058	6	0.010	0.155
Placement:Soil	0.065	1	0.065	1.023
Placement:Rate	0.215	3	0.072	1.136
Placement:Block	0.029	3	0.010	0.152
Soil:Rate	0.201	3	0.067	1.061
Soil:Block	0.773	3	0.258	4.085*
Rate:Block	1.048	9	0.116	1.847
Explained	18.448	48	0.384	6.094
Residual	9.019	143	0.063	
Total	27.467	191	0.144	

*Significant at 5 percent.

TABLE A-5

Fertilizer Price per Kg of Nitrogen
Paid by Farmer (U.S. Dollar)

	1976				1977				1978				1979
	I-III	IV-VI	VII-IX	X-XII	I-III	IV-VI	VII-IX	X-XII	I-III	IV-VI	VII-IX	X-XII	I-III
MALAWI													
Amm.Sulfate	0.99	0.53	0.53	0.53	0.58	0.57	0.57	0.57	0.57	0.77	0.77	0.77	0.77
Urea	0.88	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48
NIGER													
Amm.Sulfate					0.38	0.38	0.39	0.39		0.41	0.41		
Urea					0.31	0.31	0.31	0.31		0.33	0.33		
EGYPT													
Amm.Sulfate					0.34	0.34	0.34	0.34					
Urea					0.34	0.34	0.34	0.34					
CAPE VERDE													
Amm.Sulfate	0.76	0.76		0.63		0.76	0.54	0.54	0.54	0.54			
Urea	0.52	0.52		0.43		0.52	0.37	0.37	0.37	0.37			
SIERRA LEONE													
Amm.Sulfate	0.45		0.48	0.48		0.60	0.60						
Urea	0.31		0.33	0.33		0.41	0.41						
MALI													
Amm.Sulfate											0.49	0.49	
Urea											0.27	0.27	
MADAGASKA (Malagacy)													
Amm.Sulfate			1.12	1.12	1.22		0.99	0.99	1.03	1.03	1.13	1.15	
Urea			0.59	0.59	0.59		0.52	0.52	0.54	0.54	0.59	0.61	

Source: FAO Monthly Bulletin of Statistics, Vol. 2, March 1979.