

Effects of Sulfur-Coated Urea, Ammonium Sulfate, and Urea on the Growth of Rice in the Irrigated Arid Loamy Sand Soil

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Introduction

High temperature and low relative humidity is the characteristics of the climate in Al-Hassa oases of Saudi Arabia. Summer is the hottest and the driest season of the year, during which the maximum temperature often went up to 49°C and the relative humidity went down to 10%. Besides most soils in this area are saline to saline-alkali, and the cultivated lands are mostly limited to loamy sands to sands, with a limited area of sandy loams devoted to salt tolerant crops, such as date palm, and the local varieties of alfalfa. The total salts in irrigation water are usually greater than 1550 ppm. The soluble salts are easy to accumulate in the soils to harm the crops by the careless application of fertilizers and the improper management of the soils. However, abnormally high rate of urea is recommended to meet the requirements of crops apparently due to the high leaching and volatilization losses.

Some previous workers reported that the leaching loss of applied urea through nitrification was high in the coarse-textured soil or under excess irrigation^(2,3). Urea was easy to hydrolyze and loss as ammonia^(4,11). This volatilization loss was affected by several factors including temperature, moisture, and pH etc.^(1,5,6,7,8). Ammonia loss from ammonium sulfate occurred to a lesser extent^(6,8,11). Sulfur-coating reduced the dissolution rate of urea, and thus largely reduced the leaching and volatilization losses^(8,9,11). Stangel had described in detail the advantages of SCU and many other slow-release fertilizers in reducing fertilizer burn and nutrient losses as well as their chemical and physical properties⁽¹⁰⁾.

From the above information it seems that SCU will be less dangerous and have higher efficiency to the crops under this abnormal soil and climatic conditions of Al-Hassa oases. This experiment was conducted to compare the effects of SCU with two popular nitrogen fertilizers, ammonium sulfate and urea on the growth of rice in the irrigated arid loamy sand soil.

Materials and Methods

The experiment was conducted in the farm of Hofuf Agricultural Research Center. Three different sources of nitrogen fertilizers, urea, ammonium sulfate, and sulfur-coated urea (SCU), were made into three treatments and arranged in randomized complete block design with four

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replications for experiment as follows: A) Nitrogen at the rate of 200 kg/ha in the form of urea was divided into six equal splits and applied from the day of transplanting at the interval of 12 days, B) nitrogen at the rate of 200 kg/ha in the form of ammonium sulfate was applied as A, and C) nitrogen at the rate of 200 kg/ha in the form of SCU was applied as A. The SCU, with 29.67% of total coating, 32.05% of nitrogen, 20.88% of sulfur, 6.77% of polyethylene, and 2.02% of clodding preventor was produced by Taiwan Fertilizer Company. Its dissolution rate was 30.6% in seven days. Phosphorus at the rate of 100 kg/ha in the form of triple superphosphate was applied to all treatments soon before transplanting of rice in the same day. No potassium fertilizer was applied during the whole experiment. The soil was flooded with irrigation water for 6 times to remove the soluble salts before it was planted with rice. The results of the chemical analysis for irrigation water (ground water) were as follows: pH 7.40, EC 2.46 mmhos/cm at 25°C, total salts 1574ppm, Ca²⁺178ppm, Mg²⁺61ppm, Na⁺ 271 ppm, K⁺ 22 ppm, HCO₃-210 ppm, Cl- 478 ppm, and SO₄²⁻–345 ppm.

A dwarf type indica rice, NTU, introduced from Taiwan was transplanted on March 31, 1979, at the spacing of 25cm x 25cm with eight seedling per hill, The experiment plots were irrigated every day in the first month, and then irrigated at the intervals of every 2 to 4 days later. No pesticides was applied during the experiment. The soil and rice plant were sampled at different stages for chemical analysis. The height and tiller number of rice plants were measured and counted at different stages for statistical analysis. The rice plants were harvested on July 29 for studying their yields and yield components.

Results and Discussions

The results of soil analyses showed that the soil of the experiment plots was a loamy sand (Table 1.1). The water retention ability of the soil was very low. The irrigated water was completely removed from the soil surface in about 12 hours after irrigation. Although the soluble salts and electrical conductivity of the soil was very high to make the soil to be saline-alkali at the beginning (Table 1.1 and 1.2), they were easily removed by irrigation before and after planting with rice (Table 2). On the other hand, the pH of the soil was not affected by irrigation (Table 2). These facts suggested that the nutrients were also easy to leach out from the soil with irrigation water, but the soils were not alkalized, apparently due to the high concentration of calcium in the soil and water.

Table 1.1 The properties of the soil in the experiment plots before flooding*

Treatments	Sand %	Silt %	Clay %	Textural name	Organic matter %	pH**	EC** mmhos/cm 25°C
Urea	74.7-77.9	20.5-22.4	1.3-3.3	Loamy sand	1.13	7.8	11.30
Ammonium sulfate	73.2-77.4	20.6-23.1	1.3-3.7	Loamy sand	1.23	7.8	10.06
SCU	73.7-78.6	20.4-23.5	1.0-2.8	Loamy sand	1.08	7.8	10.76

* The figures in the table are the average values of four plots.

** pH and EC were respectively measured in 1:1 soil water suspension solution and extract.

Table 1.2. The properties of the soil in the experiment plots before flooding*

Treatments	CEC	Exchangeable bases				Available P Olsen's	Carbonate
		Ca	Mg	Na	K		
	m.e./100g	m.e./100g				ppm	%
Urea	10.0	34.6	1.03	6.90	0.38	19.6	18.6
Ammonium sulfate	9.8	30.7	1.13	6.50	0.37	18.4	20.5
SCU	9.4	33.2	1.32	7.37	0.36	20.0	18.6

* See table 1. 1.

Table 2. Changes of soil EC and pH during the experiment**

Treatments	15 days before trans- planting		3 days before trans- planting		40 days after trans- planting		80 days after trans- planting		120 days after trans- planting	
	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH
	mmhos/cm		mmhos/cm		mmhos/cm		mmhos/cm		mmhos/cm	
Urea	11.30	7.82	4.01	7.76	3.31	7.64	3.85	7.72	4.72	7.77
Ammonium sulfate	10.06	7.81	3.96	7.75	3.34	7.62	3.74	7.71	4.37	7.77
SCU	10.76	7.81	4.05	7.74	3.43	7.63	3.80	7.71	4.66	7.76

** See table 1. 1.

Table 3.1. Chemical analysis for rice plants at three different staes*

Treatments	59 days after transplating, 2nd leaf from the top			79 days after transplating, 2nd leaf from the top			105 days after transplating, whole plant		
	N	P	K	N	P	K	N	P	K
	%			%			%		
Urea	2.64	0.19	1.79	2.86	0.14	1.50	0.90	0.11	1.25
Ammonium sulfate	2.81	0.21	1.78	2.83	0.14	1.45	0.90	0.10	1.33
SCU	2.81	0.13	1.70	2.92	0.13	1.39	0.98	0.11	1.21

* See table 1. 1.

Table 3.2. Chemical analysis for rice plants at three different stages*

Treatments	59 days after transplanting, 2nd leaf from the top			79 days after transplanting, 2nd leaf from the top			105 days after transplanting, whole plant		
	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na
	%			%			%		
Urea	0.63	0.37	0.25	0.53	0.23	0.23	0.58	0.35	1.36
Ammonium sulfate	0.60	0.37	0.25	0.53	0.21	0.22	0.59	0.30	1.34
SCU	0.60	0.35	0.25	0.55	0.23	0.23	0.59	0.33	1.39

See table 1.1.

Table 3.3. Total uptake of nutrient elements by rice plants during the whole growing period.

Treatments	Nitrogen		Phosphorus		Potassium		Calcium		Magnesium		Sodium	
	kg/ha	Index	kg/ha	Index	kg/ha	Index	kg/ha	Index	kg/ha	Index	kg/ha	Index
Urea	95.4 ^{b**}	100.0	11.4 ^{b*}	100.0	133.2	100.0	61.8 ^{b*}	100.0	37.5	100.0	143.5 ^{b*}	100.0
Ammonium sulfate	92.8 ^b	97.3	10.6 ^b	93.0	137.8	103.5	61.0 ^b	98.7	31.3	83.5	138.7 ^b	96.7
SCU	121.4 ^a	127.3	14.1 ^a	123.7	151.1	113.4	73.2 ^a	118.5	40.2	107.2	172.3 ^a	120.1

* and ** : Respectively significantly different at 5% and 1% levels by Duncan's multiple range test.

The results of chemical analysis for the rice plants at the three different stages showed that the nitrogen content of rice plants in SCU treatment was slightly higher than those in urea and ammonium sulfate treatments, and the reverse was true on phosphorus and potassium contents (Table 3.1). As to calcium, magnesium, and sodium, no clear difference could be seen among the three treatments (Table 3.2). However, the total uptakes of nutrient elements by rice plants in SCU treatment were respectively increased 27.3-30% for nitrogen, 23.7-30.7% for phosphorus, 9.9-13.4% for potassium, 18.5-19.8% for calcium, 7.2-23.7% for magnesium, and 20.1-23.4% for sodium as compared with urea and ammonium sulfate treatments. These increases were significantly different at 1% level for nitrogen, and at 5% level for phosphorus, calcium, and sodium by Duncan's multiple range test (Table 3.3). Apparently the losses of applied nitrogen fertilizer in SCU treatment were lower due to its slow-release effect, and the higher uptake of nitrogen in SCU treatment promoted more growth in rice plants, and thus stimulated more uptake of the other elements to meet the growth requirement.

The data of rice plant height and tiller number at three different stages also showed that the effect of SCU was better than those of ammonium sulfate and urea, while ammonium sulfate and urea were similar (Table 4). SCU did not significantly increase the plant height, but it significantly increased the tiller number at 1% level. Field observation found that some rice plants in the ammonium sulfate treatment were seriously harmed. It was very clear that ammonium sulfate was

harmful to rice plants in the early stage after transplanting.

The yield and yield components of SCU treatment were higher and better than those of ammonium sulfate and urea treatments, while urea and ammonium sulfate treatments were similarly lower. SCU treatment obtained 18.8-19.5% increase in panicle number, 28-28.6% increase in grain yield, and 11.3-15.5% increase in straw yield as compared with the latter two treatments. The increase in panicle number was significant at 1% level, and the increases in grain and straw yields were at 5% level by Duncan's multiple range test (Table 5). Judging from the high panicle number, and straw yield, it was very likely that all treatments would have higher grain yields. However the unfavorable hot weather in the reproductive stages of rice plants prevented the normal pollination, and thus resulted in the low rate of ripened grain and low grain yields.

Table 4. The height and tiller number of rice plants at three different stages.

Treatments	59 days after transplanting		79 days after transplanting		105 days after transplanting	
	Plant height, cm	Tiller number per hill	Plant height, cm	Tiller number per hill	Plant height, cm	Tiller number per hill
Urea	43.9	40.7 ^{b***}	55.4	36.9 ^{b***}	65.4	33.4 ^{b***}
Ammonium sulfate	44.1	40.4 ^b	56.1	36.7 ^b	65.6	33.6 ^b
SCU	45.8	51.3 ^a	57.3	43.1 ^a	67.3	39.9 ^a

** Significantly different at 1% level by Duncan's multiple range test.

Table 5. Yield and yield components of rice plants.

Treatments	Panicle number per hill	Grain number per panicle	Ripened grain %	1000 grain weight g	Grain		Straw		Grain/straw ratio
					Yield kg/10m ²	Index	Yield kg/10m ²	Index	
Urea	33.4 ^{b**}	51.1	52.8	18.6	3.57 ^{b*}	100	7.06 ^{b*}	100.0	0.505
Ammonium sulfate	33.6 ^b	50.9	61.1	18.9	3.59 ^b	100.6	6.76 ^b	95.8	0.539
SCU	39.9 ^a	54.0	59.8	18.8	4.59 ^a	128.6	7.86 ^a	111.3	0.586

* and ** : Respectively significantly different at 5% and 1% levels by Duncan's multiple range test.

Summary

Three different sources of nitrogen fertilizers, urea, ammonium sulfate, and sulfurcoated urea (SCU) were used for growing rice to compare their effects in the irrigated arid loamy sand soil of Al-Hassa oases in Saudi Arabia where the soils are mostly saline to saline-alkali. Fertilizer burn on the crops in this area often occurred due to the high salt contents in the soils and irrigation water. The recommended rates of nitrogen fertilizers were very high apparently due to the high leaching and volatilization losses.

In this experiment three different sources of nitrogen fertilizers respectively at the rate of 200 kg/ha of nitrogen were divided into six equal splits and applied from the time of transplanting at the interval of 12 days. The results showed that in this coarse-textured saline soil, the effect of SCU was the best. It was the least harmful to rice plants, and the uptake of applied nitrogen increased 27.3-30%, the panicle number increased 18.8-19.5%, the grain yield increased 28-28.6%, and the straw yield increased 11.3-15.5% as compared with urea and ammonium sulfate treatments. The effects of urea and ammonium sulfate were similarly lower. However ammonium sulfate tended to be harmful to the rice plants in the early stage after transplanting.

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硫裹尿素、硫酸銨與尿素對沙漠壤質 砂土灌溉區稻作之效果

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摘 要

本試驗之目的在比較硫裹尿素、硫酸銨與尿素等三種氮素肥料沙漠壤質砂土鹽分地灌區稻作之效果。由於土壤及灌溉水之鹽分含量相當高，本地區之作物極易遭受肥料之傷害，可是一般作物之氮素肥料推薦量卻相當高，主要原因很明顯的是因為土壤保肥力差，氣溫過高，氣候過分乾燥，施下之氮肥極易漏失與逸失。本試驗將三種不同來源每公頃200公斤之氮素等分為六次，從插秧時期開始每隔12天施一次。結果顯示，在此一粗質地之鹽分地，以硫裹尿素之效果最佳。硫裹尿素不但對稻作之傷害性較少，而且與硫酸及尿素比較，其氮素總吸收量增加27.3~30%，每櫟平均穗數增加18.8~19.5%，稻谷產量增加28.0~28.6%，稻草產量增加11.3~15.5%。硫酸銨與尿素兩者比較，效果大致相同，但硫酸銨在移植後初期對稻作有傷害之傾向。

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