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Effect of sulphur coated urea on growth, yield and quality of mustard

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Abstract
Sulphur application to crop fields has drastically reduced due to the use of high-analysis fertilizers such as diammonium phosphate (DAP) instead of superphosphate and urea instead of ammonium sulphate over many years, resulting in widespread sulphur deficiency in Indian soils. Looking to the wide spread S deficiency in soils of Gujarat, a field study was conducted at the Agronomy Farm, B. A. College of Agriculture, AAU, Anand to evaluate the effect of sulphur-coated urea (SCU) as source of sulphur, besides improvement in Nitrogen use efficiency in mustard crop. The effect of Neem coated urea (NCU) coated with 6% Elemental Sulphur (ES) significantly increased mustard grain yield to the tune of 15.23% over control. However, 6% coating either Prilled or Neem coated urea enhanced Nitrogen recovery efficiency.

Keywords: Urea, nitrogen, sulphur, sulphur-coated urea, mustard

1. Introduction

Sulphur-coated urea (SCU) was developed by Tennessee Valley Authority (TVA) researchers for controlled release of nitrogen and is a popular turf fertilizer in USA (Prasad *et al.* 1971) [2]. It is currently manufactured by a number of companies in USA, Canada, Japan and China (Trenkel 1997) [6] using different techniques and sulphur (S) content may vary from 4 to 15% or even more. With the adoption of intensive farming, the farmers have shifted from organic to inorganic high analysis sulphur free fertilizers (such as diammonium phosphate (DAP) instead of superphosphate and urea instead of ammonium sulphate over many years) leading to more widespread and more intense S deficiencies in Indian soils. In early 1990's S deficiencies in Indian soils were estimated to occur in about 130 districts and recently about 45% districts of our country showed more than 40% sulphur deficiency (Tandon, 1991) [18]. Sulphur deficiencies in India are widespread and scattered. As far as 43.3 per cent soils of Gujarat is suffering from sulphur deficiency (Shukla and Tiwari, 2014) [16]. Oil content in mustard is reduced due to application of high analysis fertilizers. In sulphur deficient soil, the efficiency of applied NPK fertilizers may be seriously affected and crop yield may not be sustainable (Ahmad *et al.*, 2005) [7].

Due to continuous cropping and frequent use of S-free fertilizers in various agro-ecological zones, S is one of the most restricting nutrients for agricultural productivity in many Asian countries, leading to S deficit in soils. Sulphur shortage is a common problem all over the world and the soil sulphate budget has been affected by the ongoing removal of S from soils by plant absorption (Aulakh *et al.*, 1977) [8]. Urea is widely adopted and used nitrogenous fertilizer in the Indian agriculture. The injudicious applications of urea have raised many environmental concerns like risk of polluting groundwater owing to excess nitrate leaching. Looking to the hygroscopic nature of urea along with losses of nitrogenous fertilizer contributes to very low nitrogen use efficiency. The Sulphur Institute at Washington, DC has played a key role in focusing on sulphur deficiency in soils. SCU are formulated to improve urea-N recovery and reduce N losses, wherein urea fertilizers are coated or mixed with substances of retaining immediate N release in the soil system. To prolong N release, urea could be coated with inert materials or N stabilisers, which may increase N use efficiency, decrease the risk of N losses and increase fertiliser use efficiency. Such slow-release urea fertilizers help to increase the efficiency of applied urea-N and mitigate adverse environmental effects. SCU has so far not been evaluated as a source of S in addition to its capability to enhance the efficiency of applied fertilizer N and therefore the present study was undertaken.

2. Materials and Methods

2.1 Coating technique

Sulphur-coated urea (SCU) with graded levels of sulphur coating is not available commercially. For that, sulphur-coated urea (SCU) with 2, 4 and 6 per cent sulphur coating onto prilled urea (PU) and neem coated urea (NCU) to be used in the present study will be prepared in our research laboratory using finely ground commercial grade S (in the form of elemental sulphur). The amount of sulphur required for 2, 4 and 6 per cent coating onto 5 kg PU was 100.0, 200.0 and 300.0 g, respectively. For coating S materials on urea, neem oil was used as a sticker. Sulphur coating of PU was done in lots of 5 kg PU in a manual rotating seed treatment drum. Five kg of PU was added to the drum and then required quantity of neem oil solution added and the drum was rotated for 15 minutes to provide a fine coating of neem oil on urea.

Required amount of finely ground sulphur was added to the drum and the contents was thoroughly mixed by rotating the drum for 15 minutes. Sulphur-coated urea (SCU) made was transferred to plastic trays, which was dried overnight at room temperature (25 ± 5 °C) using air blowing fans.

2.2 Description of study area

The field experiment was conducted at College Agronomy Farm, B. A. College of Agriculture, AAU, Anand, Gujarat, India (22°35′N, 72°56′E, 45.1m above mean sea level) during the *rabi* (November-March) seasons of 2021-2022 on a sandy loam soil. The annual rainfall received during the monsoon season of the year 2021 was 941.9 mm (July-September). The soil of the experimental field had 172 kg/ha alkaline permanganate oxidizable nitrogen N (Subbiah and Asija, 1956) [17], 40.5 kg/ha available phosphorus (Olsen et al. 1954) [12], 258 kg/ha 1 N ammonium acetate exchangeable potassium (Jackson, 1973) [10] and 0.41% organic carbon (Walkley and Black 1934) [19]. The pH of soil was 8.1 (1:2.5 soil and water ratio; Jackson, 1973) [10] and sulphate sulphur extracted with 0.15% $CaCl_2 \cdot 2H_2O$ and estimated turbidimetrically was 10.8 mg/kg of soil (William & Steinbergs, 1959) [20].

2.3 Experimental treatments, design and application of fertilizers

Ten fertilizers treatments, *viz.*, PU, NCU, 2% SCPU, 4% SCPU, 2% SCPU, 2% SCNCU, 4% SCNCU, 6% SCNCU, $PU+SA_{20}$, $NCU+SA_{20}$ were laid out in a randomized block design with three replications. The experimental field was thoroughly cross cultivated with a tractor drawn cultivator. The recommended dose of $N:P_2O_5:K_2O$ for mustard crop is 50-50-0 kg/ha. The recommended quantities of N and P_2O_5 application were made through urea and SSP respectively. Half of the total doses of recommended nitrogen, full dose of phosphorus was applied at the time of sowing according to treatment and the remaining half dose of nitrogen was applied at flowering stage. Recommended dose of sulphur was applied at the time of sowing and at flowering stage as per treatments. The amount of sulphur applied was 1 kg, 2 kg and 3 kg with 2, 4 and 6% SCU, respectively.

2.4 Sowing and harvesting

Mustard variety "Gujarat Dantiwada Mustard 4" (GDM 4) was sown with a seed drill at a spacing of 45 cm × 10 cm in the second week of November, 2021. This high yielding mustard variety was released for its commercial cultivation in 2011 from the Main Castor and Mustard Research station, Sardarkrushinagar Dantiwada Agricultural University, Dantiwada. The plot size was 4.5 m × 5.0 m for each treatment. Irrigation channels measuring 1m wide were placed between the replications. Mustard received five irrigations and was harvested in the second week of March, 2022.

2.5 Studies on growth and yield attributes of mustard

Plant population was measured by per meter low length. Plant height was measured from the base of the plant (ground level) to the tip of the main shoot in centimeter (cm). Number of siliquae were counted by average number of siliquae per plant. Number of branches counted by average number of branches per plant. Number of seeds per siliqua were randomly selected, threshed and counted. 1000 seeds weight were counted from collected seed sample and weigh was recorded separately for each treatment in gram.

2.6 Seed and straw yields of mustard

Seed yield was recorded after threshing and winnowing, seeds were weighed separately and recorded as seed yield in kg per net plot which was converted into hectare and expressed as kg/ha. Stover yield was recorded by weight of fully sun-dried crop plants from each net plot were measured before threshing. After threshing, quantity of seed produced from each net plot was deducted from total weight of plant and recorded as stover yield which was converted into hectare and expressed as kg/ha.

2.7 Chemical analysis of soil samples

The soil samples were analyzed for important soil properties *viz.*, pH (1:2.5 soil and water ratio; Jackson, 1973) [10], EC (1:2.5 soil and water ratio; Jackson, 1973) [10], OC (Walkley and Black 1934) [19], available nutrients *viz.*, N (Subbiah and Asija 1956) [17], P_2O_5 (Olsen *et al*. 1954) [12], K_2O (Jackson,1973) [10] and S extracted with 0.15% $CaCl_2 \cdot 2H_2O$ and estimated turbidimetrically (William & Steinbergs, 1959) [20].

2.8 Chemical analysis of plant samples

The total N was determined by digestion of plant samples with concentrated sulphuric acid. The N content of digested sample is determined using micro kjeldahl apparatus. For the estimation of P, K and S contents in plant, samples weredigested in di-acid mixture (HNO_3: HClO4 - 3:1) and fine volume was prepared with double distilled water. The extract was filtered through Whatman filter paper No.42, which was used for total element analysis by following standard methodologies for Total N (Kjeldahl's digestion method and crude protein content (Total nitrogen multiply by 6.25) by Jackson (1973) [10]. For Total S (Turbidimetry) by Williams and Steinbergs (1959) [20] and oil content (Soxhlet extraction method) by Sadasivam *et al*. (2004) [14].

2.9 N and S Uptake

The concentration of major nutrients determined in plant was expressed in per cent. The uptake of major nutrient by mustard grain and straw was calculated using below mentioned formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (per cent)} \times \text{yield (kg ha}^{-1}\text{)}}{100}$$

2.9 Nitrogen use-efficiencies

2.9.1 Agronomic Efficiency

Agronomic efficiency (AE) is calculated in units of yield increase per unit of nutrient applied. AE proposed the direct production impact of an applied fertilizer and directly reflects to economic return.

$$AE = \frac{\text{Grain yield in treated plot (kg ha}^{-1}) - \text{Grain yield in control plot (kg ha}^{-1})}{\text{Amount of S applied (kg ha}^{-1})}$$

2.9.2 Recovery Efficiency
Recovery efficiency (RE) is one of the more complex forms of NUE expressions and is commonly defined as the ratio of differences in nutrient uptake by plants due to fertilized and unfertilized treatments and quantity of nutrient applied.

$$RE = \frac{\text{S uptake in treated plot (kg ha}^{-1}) - \text{S uptake in control plot (kg ha}^{-1})}{\text{Amount of S applied (kg ha}^{-1})} \times 100$$

2.10 Statistical analysis
Statistical analysis for experimental data of different characters was carried out on computer facility at Department of Agricultural Statistics, B. A. College of Agriculture, AAU, Anand. Standard error of mean (S.Em), Critical difference (CD) and Co-efficient of variation (CV %) were worked out for each observations per the method suggested.

3. Results and Discussion
3.1 Growth characters and yield of mustard
Among the ten treatments, application of recommend dose of nitrogen through 6 % S coated neem coated urea proved significantly superior in terms of enhancing the growth and yield parameters *viz*., plant height at harvest, number of siliquae per plant and number of branches per plant over control. The results were at par with recommend dose of nitrogen through 6% SCPU, recommend dose of nitrogen through 2% SCNCU and recommend dose of nitrogen through 4% SCNCU over rest of the treatments.

Table 1: Effect of sulphur-coated urea on growth and yield attributes of mustard

Treatment	Plant population (m-1 row length) (cm)		Plant height (cm)		No. of siliquae /plant	No. of branches /plant	No. of seeds /siliqua	Test weight (g)
	15 DAS	Harvest	30 DAS	Harvest				
100% RDN through Prilled urea (PU)	13.12	7.80	15.76	178.92	276.47	15.60	12.87	5.49
100% RDN through Neem coated urea (NCU)	13.16	7.93	15.95	179.13	277.93	15.73	12.93	5.43
100% RDN through 2% S coated prilled Urea	13.21	7.80	17.03	179.66	284.00	16.60	13.13	5.48
100% RDN through 4% S coated prilled Urea	13.39	7.87	17.67	181.50	285.73	17.40	13.20	5.48
100% RDN through 6% S coated prilled Urea	13.63	8.07	17.65	188.51	292.80	17.67	13.87	5.50
100% RDN through 2% S coated NCU	13.21	7.93	18.51	185.88	282.47	17.27	13.53	5.49
100% RDN through 4% S coated NCU	13.60	8.07	17.21	188.72	297.27	17.47	13.80	5.49
100% RDN through 6 % S coated NCU	13.69	8.13	19.06	193.24	311.73	17.87	14.53	5.51
T_1 + 20 kg S through gypsum/ha	13.25	7.67	16.97	187.01	281.00	16.33	13.13	5.41
T_2 + 20 kg S through gypsum/ha	13.34	7.87	17.31	187.03	285.33	16.60	13.20	5.49
S.Em±	0.32	0.23	0.65	2.95	6.76	0.21	0.34	0.16
CD (P=0.05)	NS	NS	NS	8.77	20.10	0.62	NS	NS
CV (%)	4.15	4.98	6.53	2.76	4.08	2.16	4.38	5.12

Table 2: Effect of sulphur-coated urea on yield of mustard

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)
100% RDN through Prilled urea (PU)	2105	5383
100% RDN through Neem coated urea (NCU)	2225	5423
100% RDN through 2% S coated prilled Urea	2273	5577
100% RDN through 4% S coated prilled Urea	2326	5545
100% RDN through 6% S coated prilled Urea	2410	5886
100% RDN through 2% S coated NCU	2341	5328
100% RDN through 4% S coated NCU	2448	5545
100% RDN through 6 % S coated NCU	2564	6777
T_1 + 20 kg S through gypsum/ha	2269	5343
T_2 + 20 kg S through gypsum/ha	2305	5441
S.Em±	58	341
CD (P=0.05)	171	NS
CV (%)	4.29	10.50

3.2 Seed and stover yield
Among the ten treatments, application of recommend dose of nitrogen through 6 % S coated neem coated urea proved significantly superior in terms of enhancing seed and stover yield. In case of seed yield, it was being at par with recommend dose of nitrogen through 6% SCPU and recommend dose of nitrogen through 4% SCNCU over rest of the treatments.

3.3 Nitrogen content and uptake
Application of N as uncoated PU and NCU increased N concentration and uptake in mustard seed and stover (Table 3). Nitrogen content in mustard seed and stover was influenced by different sulphur application treatments but could not reach to a level of significance. S application had no significant effect on N uptake by mustard seed. While, N uptake by stover was significantly influenced by sulphur application treatments. Among the different treatments, application of 6 % S coated NCU was calculated significantly higher N uptake in stover, being at par with 6% S coated prilled Urea over control.

3.4 Sulphur content and uptake
S content in seed and stover of mustard was increased with

the increase in level of sulphur but it was not significantly affected by different sulphur fertilizer application. (Table 4). S uptake by seed and stover of mustard was significantly influenced by different sulphur application treatments. Among the treatments, application of 6% S coated NCU significantly influenced S uptake by mustard seed, being at par with all the treatments except the treatment, recommend dose of nitrogen through Prilled urea, recommend dose of nitrogen through Neem coated urea and recommend dose of nitrogen through 2% S coated prilled Urea over control. In case of S uptake by mustard stover, significantly higher S uptake by mustard stover was observed under application of 6% S coated NCU, being at par with recommend dose of nitrogen through prilled urea along with 20 kg S through gypsum/ha and recommend dose of nitrogen through Neem coated urea along with 20 kg S through gypsum/ha over control.

3.5 Protein and oil content (%) of mustard seed
Crude protein content and oil content was not affected on significant basis due to sulphur application treatments (Table 5). Oil content and protein content in mustard seed was increased with the increased application of sulphur fertilizer through different source but it was found non-significant.

3.6 Utilization efficiency of nitrogen
The data pertaining to the agronomic efficiency as affected by different sulphur application treatments are presented in Table 6. Among the different treatments, highest agronomic efficiency was obtained with recommend dose of nitrogen through 2% S coated prilled Urea followed by recommend dose of nitrogen through 2% S coated Neem coated Urea. While, lowest agronomic efficiency was observed under recommend dose of nitrogen through neem coated urea along with 20 kg S through gypsum/ha followed by recommend dose of nitrogen through prilled urea along with 20 kg S through gypsum/ha.

3.7 Post-harvest soil properties of mustard crop
A perusal of analytical values pertaining to after harvest soil properties as shown in Table 7 in terms of Electrical conductivity (dS/m), pH, Organic carbon (%), Av. N, P_2O_5, K_2O and S revealed that none of the S application treatments had significant influence on soil reaction, salt content as well as organic content in after harvest soils.
The after-harvest soil properties were not affected significantly could be ascribed to the buffering capacity of soil. Though, the changes in soil properties could not reach to the level of significance, might be due to buffering capacity of the soil.

Table 3: Effect of sulphur-coated urea on nitrogen content and uptake in mustard seed and stover

Treatment	N content (%)		N uptake (kg/ha)	
	Seed	Stover	Seed	Stover
100% RDN through Prilled urea (PU)	2.674	0.572	56.77	31.07
100% RDN through Neem coated urea (NCU)	2.694	0.577	59.93	31.06
100% RDN through 2% S coated prilled Urea	2.728	0.583	62.14	32.64
100% RDN through 4% S coated prilled Urea	2.738	0.596	63.54	33.01
100% RDN through 6% S coated prilled Urea	2.746	0.625	65.01	36.73
100% RDN through 2% S coated NCU	2.735	0.584	64.09	31.16
100% RDN through 4% S coated NCU	2.747	0.602	67.73	33.45
100% RDN through 6 % S coated NCU	2.772	0.640	71.00	43.35
T_1 + 20 kg S through gypsum/ha	2.715	0.580	61.79	30.97
T_2 + 20 kg S through gypsum/ha	2.723	0.582	62.53	31.66
S.Em±	0.13	0.02	4.02	2.46
CD (P=0.05)	NS	NS	NS	7.32
CV (%)	8.56	6.15	10.96	12.72

Table 4: Effect of sulphur-coated urea on protein and oil content of mustard seed

Treatment	Oil content (%)	Protein content (%)
100% RDN through Prilled urea (PU)	37.82	16.71
100% RDN through Neem coated urea (NCU)	37.87	16.84
100% RDN through 2% S coated prilled Urea	38.29	17.05
100% RDN through 4% S coated prilled Urea	38.46	17.12
100% RDN through 6% S coated prilled Urea	38.70	17.16
100% RDN through 2% S coated NCU	38.45	17.09
100% RDN through 4% S coated NCU	38.58	17.17
100% RDN through 6 % S coated NCU	38.82	17.33
T_1 + 20 kg S through gypsum/ha	39.10	16.97
T_2 + 20 kg S through gypsum/ha	39.28	17.02
SEm±	1.43	0.84
CD (P=0.05)	NS	NS
CV (%)	6.44	8.56

Table 5: Effect of sulphur-coated urea on sulphur content and uptake in mustard seed and stover

Treatment	S content (%)		S uptake (kg/ha)	
	Seed	Stover	Seed	Stover
100% RDN through Prilled urea (PU)	0.363	0.246	7.69	13.36
100% RDN through Neem coated urea (NCU)	0.370	0.249	8.22	13.39
100% RDN through 2% S coated prilled Urea	0.373	0.254	8.47	14.09
100% RDN through 4% S coated prilled Urea	0.377	0.257	8.79	14.29
100% RDN through 6% S coated prilled Urea	0.384	0.261	9.10	15.40
100% RDN through 2% S coated NCU	0.375	0.255	8.78	13.58
100% RDN through 4% S coated NCU	0.379	0.262	9.34	14.49
100% RDN through 6 % S coated NCU	0.390	0.269	10.01	18.26
T_1 + 20 kg S through gypsum/ha	0.429	0.284	9.85	15.12
T_2 + 20 kg S through gypsum/ha	0.431	0.289	9.78	15.61
SEm±	0.02	0.01	0.43	0.90
CD (P=0.05)	NS	NS	1.28	2.67
CV (%)	6.81	6.76	8.29	10.54

Table 6: Effect of sulphur-coated urea on different nutrient efficiency indices

Treatment	Agronomic efficiency (kg grain increasedkg-1 N applied)	Recovery efficiency (%)
100% RDN through Prilled urea (PU)	-	-
100% RDN through Neem coated urea (NCU)	-	-
100% RDN through 2% S coated prilled Urea	168	78
100% RDN through 4% S coated prilled Urea	110	55
100% RDN through 6% S coated prilled Urea	101	47
100% RDN through 2% S coated NCU	116	56
100% RDN through 4% S coated NCU	111	56
100% RDN through 6 % S coated NCU	113	59
T_1 + 20 kg S through gypsum/ha	8	10
T_2 + 20 kg S through gypsum/ha	4	08

Table 7: Effect of sulphur coated urea on after harvest soil EC, pH, OC, available N, P_2O_5, K_2O and S

Treatment Details	EC	pH	OC	Av. N	Av. P	Av. K	Av. S
	(dS/m)		(%)		(kg/ha)		(mg/kg)
Initial soil value	0.19	8.08	0.41	172	40.5	258	10.8
100% RDN through Prilled urea (PU)	0.22	7.99	0.42	174	36.39	237	9.44
100% RDN through Neem coated urea (NCU)	0.23	7.94	0.43	174	36.65	239	9.61
100% RDN through 2% S coated prilled Urea	0.24	7.93	0.44	176	36.88	240	10.90
100% RDN through 4% S coated prilled Urea	0.23	7.92	0.44	177	37.24	240	10.98
100% RDN through 6% S coated prilled Urea	0.26	7.87	0.46	179	37.42	242	11.05
100% RDN through 2% S coated NCU	0.24	7.83	0.43	177	36.91	240	10.96
100% RDN through 4% S coated NCU	0.26	7.80	0.44	179	37.41	241	11.04
100% RDN through 6 % S coated NCU	0.24	7.77	0.46	184	37.49	241	11.11
T_1 + 20 kg S through gypsum/ha	0.26	7.73	0.46	180	37.70	242	11.60
T_2 + 20 kg S through gypsum/ha	0.25	7.93	0.48	182	38.03	240	11.83
SEm±	0.01	0.45	0.02	9.41	1.86	11.24	0.53
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.75	9.91	7.65	9.14	8.68	8.11	8.51

Response of sulphur coated urea in different crops are available in literature. The main objective of the present study was to evaluate SCU with graded levels of sulphur coatings as well as their effect on nitrogen use efficiency. No such report is available, since most of the earlier studies involved SCU with fixed S coating only. For this reason, we prepared 2, 4 and 6% S coated urea in our own research laboratory.

Higher nitrogen use efficiency with SCU over PU obtained in the present study is in accord with reports from earlier researchers (Prasad *et al*. 1971;Bijay-Singh and Katyal 1987)[3, 1]. This could be due to slow release of N from SCU (Reddy and Prasad 1975)[5] and therefore reduced N losses (Prasad and Rajale 1972; Prakasa Rao and Prasad 1980)[2, 4]. This study also brought out that N application increases S uptake by mustard.

Oilseed crops generally respond to the application of sulphur. So, we conducted this study because elemental sulphur is much costly in India and in other developing countries, which do not have sulphur deposits and most of it hasto be imported. It is expected as application of split sulphur coated urea release nitrogen at slow rate in soil which gave more available nitrogen as compare to controlled treatment, which was enhances the cellular activity, photosynthetic efficiency and merismetic activity leading to tissue differentiation from somatic to reproductive and development of floral primordial might have been enhance flowering which latter developed to siliquae and at last it increases the yield of mustard crop. These results are in accordance with the finding of Khan *et al*. (2015)[11] in maize and Guggari (2018)[9] in pearl millet. Among different S application treatments, recommend dose of nitrogen through 2% S coated prilled urea showed highest agronomic efficiency over rest of the treatments. While, application of recommend dose of nitrogen through 2% S coated prilled urea treatment, over control also recorded higher recovery efficiency, owing lesser amount of S supplementation (Shivay *et al*. (2016)[15] in rice and Pooniya *et al*. (2018)[13] in maize).

SCU should be promoted as a source of S as well as an enhanced efficiency of nitrogen fertilizer. On the basis of experimental results, it can be concluded that application of recommend dose of nitrogen through 6 % S coated neem coated urea fertilizer increases growth and yield of mustard crop.

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