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IMPACT OF VITAL UREA (SULFUR-COATED UREA) AND PLAIN UREA WITH SULFUR ON GROWTH AND YIELD OF WHEAT

TEHMINA ANJUM[1], AHMAD UMAIR[2], ZILL-E-HUMA AFTAB[1*], WAHEED AKRAM[1], MUHAMMAD SHAHID SALEEM[2], SUMERA AKRAM [2]

[1]*Department of Plant Pathology, Faculty of agricultural Sciences, University of the Punjab, Lahore, Pakistan.*
[2]*Vital Green Agri nutrients, Private Limited, Lahore, Pakistan*

**Corresponding Author's Email: huma.dpp@pu.edu.pk*

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Abstract:

The losses of nitrogen in intense cropping regions are of huge concern for growers due to ammonia volatilization leading to waste of resources and contamination in environment. In recent years sulfur has acquired significant importance in balanced crop nutrition. It has been observed that sulfur effectively decrease volatilization and increase the use efficiency of nitrogen reducing the losses of nitrogen. Therefore, a field experiment was designed to compare the yield outcomes by assessing the impact of ScU and N=SCU N on growth of the crop. These results were analyzed by evaluating the effects of treatments on the key yield parameters such as grain weight, number of tillers and total grain yield to quantify the improvements facilitated by ScU in comparison to the conventional urea products. The results were statistically analyzed using Fisher's analysis of variance technique. The treatments were compared using the HSD Tukey's test at a 5% probability level. The treatment labeled Sulfur-coated Urea (ScU) demonstrated the significantly highest number of grains per spike (55), a 1000 grain weight of (42.70 g) and a grain yield of (4.30 t ha-1). On the other hand, the control treatment displayed relatively lower numbers of grains per spike (51), a 1000 grain weight of (32.88 g), and a grain yield of (3.15 t ha^{-1}). The proposed study was planned for growth and yield enhancement in wheat under different nutrient conditions.

Keywords: Wheat, nitrogen fertilizers, sulfur-coated urea, plain urea, RCBD, nitrogen use efficiency (NUE), nutrient uptake, high yield, harvest index.

Introduction

Wheat is a vital cereal crop and a staple food in Pakistan, cultivated extensively across the country. It contributes 2.2 % to Pakistan's GDP and around 10.3% to the rural economy, making it one of the country's principal crops. Being one of the major crops it accounts for 2.2% of the GDP and approximately 10.3% of the agrarian economy of Pakistan (Ali *et al*., 2022). As stipulated by an assessment, per capita consumption of wheat in Pakistan is 124 kg/year, and its flour contributes 72% of daily caloric intake (Elahi *et al*., 2022). Wheat is an essential source of dietary protein, calories, minerals, carbohydrates, and vitamins, providing significant nutrition to the population (Dhanda *et al*., 2004). Wheat contributes 20% to the daily human diet and is enriched with 55% carbohydrates and 8-12% proteins (Dawar *et al*., 2022). Pakistan ranks as the 7th largest wheat producer globally, but it faces challenges in achieving higher yields compared to other countries (Land, 2008). The average grain yield in Pakistan stands at 2750 kg ha^{-1}, lower than the global average of 3210 kg ha^{-1} (Pooniya and Shivay, 2011).

Several factors contribute to crop failures, including inadequate water for irrigation during crucial crop stages, weed infestation, late sowing, improper seed rate and sowing methods, insufficient plant density, and nutrient deficiencies. The excessive use of agricultural inorganic chemicals for productivity enhancement is leading to the deterioration of primary resources such as water, air, nutrients and the environment (Pooniya and Shivay, 2011). To address this, it is essential to adopt environmentally-friendly and sustainable approaches that ensure high yields and promote the well-being of both ecosystems and human society (Kennedy *et al*., 2004).

Among all essential nutrients, nitrogen is the most vital element for plant growth, being a key component of chlorophyll and playing a critical role in photosynthesis. Proper management of nitrogen fertilizers can significantly enhance grain weight, yield and protein content, particularly in cereal crops (Dawar *et al*., 2022). Water-soluble fertilizers like urea can have low agronomic efficiency due to factors like leaching, decomposition, luxury consumption, and toxicity from excessive application. Nitrogen losses can range from 10% under favorable soil conditions to 75% under poor conditions. Minimizing these losses presents a significant opportunity for nitrogen conservation (Rindt *et al*., 1968). Nitrogen misplaced through leaching contributes to contamination of groundwater, water bodies, freshwater lakes, eutrophication, and disruption of biodiversity. Volatilized nitrogen in the form of methane (CH_4) and ammonia (NH_3) contributes to the emission of greenhouse gasses and the occurrence of acid rain (Asghar *et al*., 2022).

It is important to use our resources adequately in order to produce food for growing global population sustainably. By the mid-term (2050), the demand for wheat is projected to increase to around 840 million tons from the ongoing produce of 750 million tons (FAO, 2018). Cereal crops, including wheat, typically have nitrogen use efficiency (NUE) below 50%, as they require substantial nitrogen for optimal economic yields (Ghafoor *et al*., 2021).

Sulfur (S) is essential for the formation of amino acids like methionine and cysteine in plants. Maintaining a balanced sulfur update slows down oxidative processes and enhances the reduction mechanism (Dawar *et al*., 2022). Sulfur is a cost-effective coating agent compared to other polymeric materials, such as polyethylene or polyurethane. It is easily manageable in its molten state for coating granules or prills. Additionally, sulfur can provide residual benefits on sulfur-deficient soils (Rindt *et al*., 1968).

After urea application, soil pH and urea concentration rapidly increase in the microsite where the fertilizer is applied. Urease enzymes initiate the hydrolysis of urea, leading to nitrogen (N) losses and accumulation of NH^{4+}. This can result in seedling damage and hinder the germination of plant crops (Khan *et al*., 2015). The use of “S” element is secondary, fungicidal, and has the acidic characteristics that neutralize the soil alkalinity. Thus, the uncontrolled use of N without the coated layer of “S” leads to maximum N leaching and decreases the NUE (Ghafoor *et al*., 2021). A study by (Shivay *et al*., 2016) reported that the use of 5% ScU (Sulfur-Coated Urea) application fulfilled 50% of the wheat crop's sulfur requirements and increased nitrogen recovery efficiency by 60%. Thus, the recommendation by Shivay *et al*. (2016) to use ScU for both sulfur supplementation and improving nitrogen fertilizer efficiency in wheat cultivation served as the impetus for the current study.

MATERIALS AND METHODS

Experimental Site and details of treatments

The study aimed to investigate the influence of sulfur-coated urea fertilizer on the growth and yield parameters of wheat crop. Two doses of sulfur-coated urea fertilizers (ScU (13% S: 32% N) and SCUN). The field experiment was conducted during the winter season of 2022-23 at the research area of Vital Green Pvt. Ltd (DRF), Lahore situated in the Punjab Province of Pakistan. The experiment followed a Randomized Complete Block Design (RCBD), with each plot measuring 1.5 m x 3.0 m. Three replicate plots were included in each treatment.

Field trial and crop management practices

The seed of wheat variety 'Bhakkar Star' was procured from the Ayub Agriculture Research Centre (AARI) which was used in this study with a seed rate of 50 kg/acre and was sown on November 29th, 2022. The recommended dose of fertilizers for wheat e.g. phosphorus (90 kg P_2O_5 ha^{-1}) as DAP fertilizer was applied at the time of sowing, potash (60 kg K_2O ha^{-1}) as sulfate of potash fertilizer at the booting stage, and nitrogen as coated and/or uncoated Urea fertilizer, was applied in two splits (tillering and booting) along with irrigations as per treatments. Zinc was applied during the tillering stage as well.

All other agronomic practices were maintained consistently throughout the experiment. A total of five irrigations were applied at different growth stages of wheat. Weeds were controlled by the chemical spray of Pinoxaden and Bromoxynil for narrow and broad leaf weeds, respectively, applied after 40 days of sowing. The sowing of the wheat crop was performed by dropping the seeds into furrows by hand, locally known as pora method (Khan *et al*., 2000). The rest of the recommended agronomic practices performed are given below:

The detail of treatments is given below;

T_0 = Control (0 nitrogen)

T_1 = ScU (Sulfur-coated Urea) (25 kg packing) (13% S: 32% N)

T_2 = Plain Urea (50 kg packing) (46% Nitrogen)

T_3 = Urea (Urea in quantity providing the same N % as Sulfur-coated Urea) (17 kg plain urea is equal to 1 bag of ScU)

Evaluation of growth and yield parameters

Different growth and yield parameters of wheat crop were analyzed at the final harvesting stage. Five plants were randomly selected from each plot for data analysis.

- The parameters measured included the length of spikes and plant height with the help of a meter rod.
- The number of productive tillers was counted along a designated one-meter row in each plot and the numbers were converted to per square meter (m^{-2}) value.
- The spikelet's per spike was recorded for each spike.
- The quantity of grains was counted after threshing the spikes.
- Stochastic sampling of grains was done from each plot to record the 1000-grain weight.
- A count of one thousand grains was obtained from the sample and their collective weight was recorded.

The entire plot was harvested and bundled using ropes, with a label attached to each bundle for identification. The dried bundles from each plot were weighed individually to determine the biological yield. After measuring the biological yield, each bundle from the net plot was threshed. The resulting produce from each net plot was then used to calculate the grain yield in metric tons per hectare (t/ha). The harvest index was determined using the formula proposed by Singh and Stoskopf (1971).

$$Harvest\ index = \frac{Grain\ yield\ (q\ ha^{-1})}{Biological\ yield\ (q\ ha^{-1})} \times 100$$

Statistical Analysis

The results were interpreted using Fisher's ANOVA to identify substantial differences among the fertilizer treatments. The Tukey's HSD test at a 5% probability level was applied for pairwise comparisons which helped in precise identification of differences between treatments.

This process ensured precise and consistent analysis of the data. Furthermore, multivariate analyses were performed with the Statistix 8.1 software to interpret the correlation between crop parameters and fertilizer treatments. These analyses assisted in recognizing patterns and relationships within the data offering a detailed view of effects caused by different treatments on yield outcomes.

Results

Agronomic Traits

Figure 1 illustrates the effect of various treatments on fundamental agronomic traits of wheat plants, including spike length, plant height, number of spike lets per spike, and productive tiller per square meter, in response to sulfur-coated and conventional urea fertilizers. When compared to the control treatment where no nitrogen fertilizer was applied, the rest of the treatments containing coated or uncoated urea fertilizer positively affected agronomic parameters (Figure 1).

The application of sulfur-coated fertilizer (T1) showed an increase of 3.7-, 2.8-, and 3.9% in plant height, spike length and number of spikelet per spike and productive tillers, correspondingly, compared to the control (T0) treatment. Similarly, over T4 treatment application (Urea N %= SCU N %), coated urea fertilizer yielded 2.4% more spikelets per spike (Figure 1).

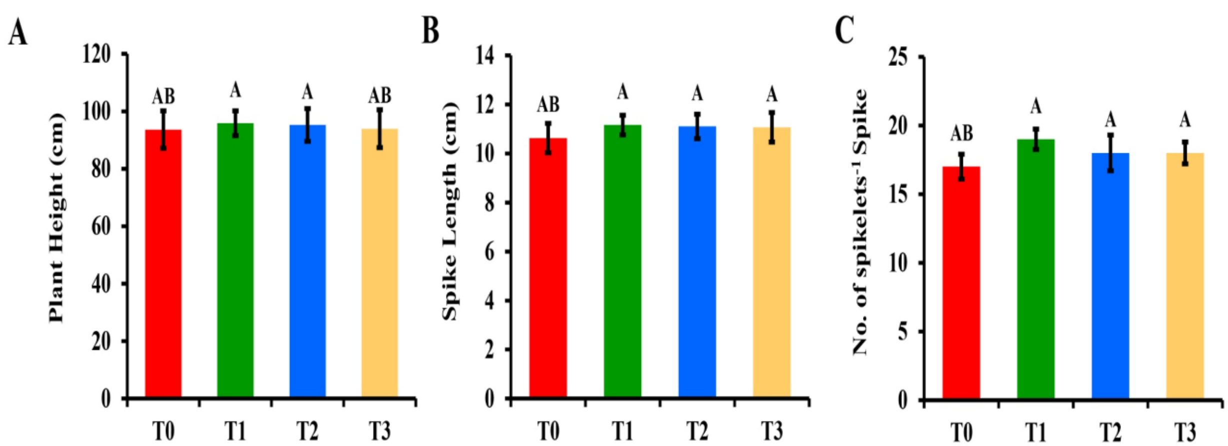

Figure 1: Effect of coated urea fertilizer on agronomic traits of wheat plants. A= Effect of coated fertilizer on plant height; B= Effect of coated fertilizer on spike length; C= Effect of coated fertilizer on number of spikelet per spike; Vertical bars represent standard error between different replicates of the same treatment. Capital letters shows level of significance among different treatment according to ANOVA and DNMRT at *p*>0.05.

Crop Yield

Figure 2 specifies the influence of the application of urea coated with sulfur and uncoated urea fertilizers on the yield-related parameters of wheat. The sulfur-coated urea fertilizers (T1) resulted in pronounced differences in the grains per spike, the weight of 1000 grains, and the grain yield compared to the non-treated control (T0) and conventional urea application (T2) (Figure 2). The usage of sulfur-coated urea fertilizers (T1) increased quantity of productive tillers, grains per spike, the weight of 1000 grains, and the grain yield up to 2.1, 47.1, 27.3, and 32.4% compared to the non-treated control (T0) plants (Figure 2). Among sulfur-coated and non-coated urea fertilizers, the application of sulfur-coated resulted in 4.7-, 1.4-, 6.2% increased grains per spike, the weight of 1000 grains, and the grain yield, respectively (Figure 2). Similarly, sulfur-coated urea (T1) yielded relatively higher amounts of grains per spike, a weight of 1000 grains, and the grain yield up compared to the T4 (where the quantity of conventional urea is applied to provide the same percentage of N as sulfur-coated urea is providing) (Figure 2).

Similarly, the application of coated urea (T1) increased biological yield up to 31.7-, 5.73% compared to the non-treated plants (T0) and conventional urea application (T2) (Figure 2 D). However, the harvest index was least affected by the application of different treatments (Figure 2 E).

A positive correlation was seen among different agronomic and yield parameters from the data of all treatments (Figure 3A). Similarly, principal component analysis presented >80% of the variance (Figure 3B). This effectively demonstrated the differences in the treatment responses.

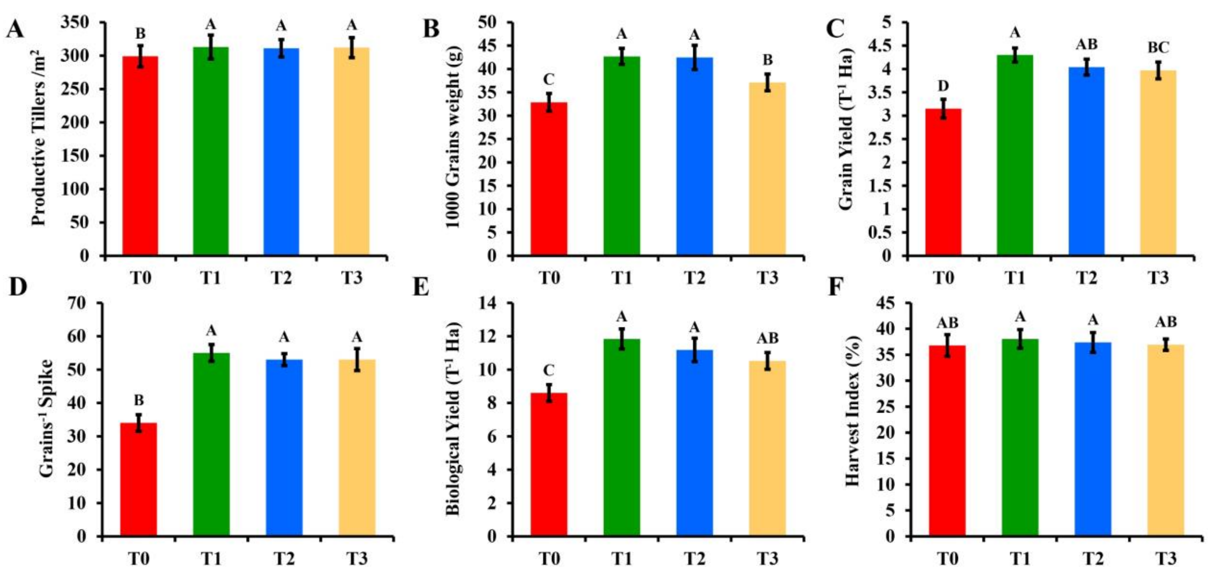

Figure 2: Effect of coated urea fertilizer on agronomic traits of wheat plants. A= Effect of coated fertilizer on productive tillers per plant; B= Effect of coated fertilizer on weight of 1000 grains; C= Effect of coated fertilizer on grain yield; D= Effect of coated fertilizer on grain per spike; E= Effect of coated fertilizer on biological yield; F= Effect of coated fertilizer on harvest index. Vertical bars represent standard error between different replicates of the same treatment. Capital letters show level of significance among different treatment according to ANOVA and DNMRT at *p*>0.05.

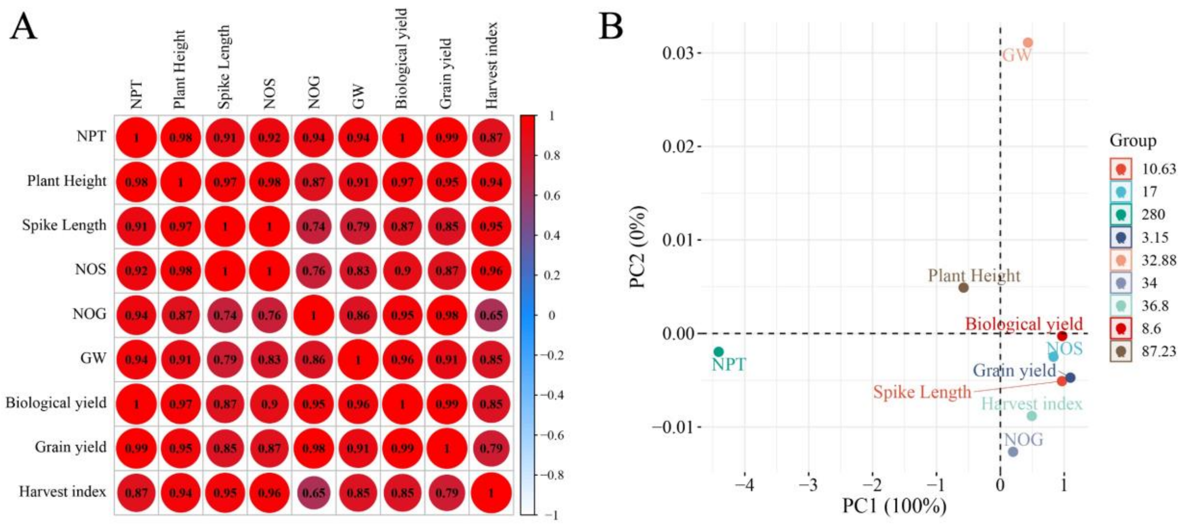

Figure 3: Multivariate data analysis showing (A) heat map of correlation analysis and (B) PCA (principal component analysis) based on the studied agronomic and yield-related parameters subjected to different treatments.

Discussion

Ammonia is a nitrogenous chemical compound that is lost from the soil due to ammonia volatilization. This results in environmental pollution and lower yields of crops. Different methods have been suggested to manage nitrogen losses to enhance nutrient utilization by the crops. The coating of conventional fertilizers is the most effective strategy to reduce nitrogen losses (Dimkpa *et al*., 2020). This study used sulfur as a release barrier to conventional urea fertilizer. Sulfur is an important plant nutrient and is degradable in the environment. Hence, sulfur was chosen as a coating agent in this study.

In the present study, it was observed that the application of conventional urea fertilizer and/or coating of sulfur on urea fertilizer significantly improved growth and yield parameters of the wheat plant as compared to the control plants.

The development of wheat crops, including shoot length, generally increased due to the impact of nitrogen fertilizers in comparison to the control. Many bio-molecules including, many amino acids, proteins, and phytohormones, are composed of nitrogen. Nitrogen is primarily engaged in the development mechanisms, like chromosome duplication, and the formation of nuclear protein and deoxyribonucleic acids (Mitra, 2017). Auxin are mainly responsible for the elongation of cells and plant height that are biosynthesized from tryptophan amino acid. It has been reported that the availability of nitrogen increases the production of tryptophan inside plants (Sarwar *et al*., 1992). This in turn could be responsible for the increased height of plants when urea fertilizer was applied in the fields.

The optimum nitrogen availability increases the yield of carbohydrates that could be employed for the progression of the plants. Encapsulated nitrogen fertilizer can be the reason for the constant nitrogen accessibility to the wheat crop (Ruisi *et al*., 2016). This ultimately resulted in improved growth parameters as was observed in our study. The plants receiving coated urea fertilizer showed significantly increased growth and yield parameters compared to the plants receiving non-coated urea fertilizer (Liang *et al*., 2006; Azeem *et al*., 2014; Gil-Ortiz *et al*., 2020). Regarding the effects of urea fertilizer in different formulations, figure 2 shows that the number of tillers, spike length, grain weight, and subsequent yield of wheat plants were significantly higher when sulfur-coated urea was applied than the plants receiving conventional urea fertilizer. Figure 3 demonstrates the interactive impact of different urea treatments on wheat growth and yield parameters. The grain yield and 1000 grains weight of wheat plants increased significantly by using sulfur-coated urea respectively over the conventional urea and non-treated control. As was seen, the effect of sulfur-coated urea was more pronounced on yield parameters compared to the plant height. That might be attributed to the combined synergetic effect of sulfur with nitrogen fertilizer as sulfur is a component of different amino acids, proteins, and coenzymes (Rossini *et al*., 2018). Secondly, the coating material prevents surrounding water and counter-ion from a reaction with urea fertilizer that minimizes the loss of nitrogen in the atmosphere. Hence, the increased yield of wheat receiving coated urea fertilizers may result from the protection of nitrogen brought by the sulfur coating.

Our results follow previous research performed by Ghafoor *et al*. (2022). They showed that the plants performed significantly better in terms of vegetative growth and yield when provided with the coated urea fertilizer. In another study, use efficiencies of N, P and K were increased in wheat crop with the coating on fertilizers (Irfan *et al*. 2018).

Conclusion

The recent experimental study has unveiled the significant importance of nitrogen and sulfur in enhancing wheat productivity. The application of nitrogen with a sulfur coating has demonstrated a substantial impact on the growth and yield of wheat plants, surpassing the performance of plain urea. The observed significant improvements in various agronomic and yield contributing parameters including grains per spike, 1000 grain weight and grain yield validate the efficacy of this approach as application of Vital urea (sulfur-coated urea) less in amount than Plain urea gave better results that showed efficiency of slow-release fertilizers. By adopting nitrogen with sulfur-coated technology, farmers can optimize their wheat yields and contribute to sustainable agriculture practices.

Conflicts of interest

There is no conflict of interest related to this article.

Author's contribution

All authors have contributed equally

Funding statement

There is no funding to show

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