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Optimizing nitrogen and sulphur fertilization for improved wheat productivity

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Abstract

A field experiment entitled “Optimizing Nitrogen and Sulphur Fertilization for improved Wheat Productivity” was conducted during the *Rabi* season of 2024 at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments replicated three times. Results indicated that the combined application of nitrogen and sulphur significantly improved wheat growth, yield components, and biomass. The highest grain and straw yield were recorded under 150 kg N/ha + 40 kg S/ha (T9). Harvest index was less affected, suggesting that nutrient management primarily enhanced total biomass rather than its partitioning. However, high temperatures above 30 °C during reproductive and grain filling stages adversely affected productivity. The study concludes that optimum nitrogen and sulphur application, coupled with climate-resilient management practices, is essential to achieve sustainable wheat yields under the agro-climatic conditions of Prayagraj.

Keywords: Wheat, nitrogen, sulphur, heat stress, nutrient management

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops of the world, belonging to the family Poaceae (Gramineae). It has a wide geographical adaptability, unique chemical composition, high nutritional value, functional health benefits, and diverse end-uses such as food, feed, and non-edible purposes (Rani *et al.*, 2024) ^[13]. Owing to its dominance in global area and production, wheat is popularly referred to as the “King of Cereals.” It is cultivated for its seed, a cereal grain that is a staple food for a majority of the global population. Nutritionally, wheat compares favorably with other cereals, especially in terms of protein content. Its composition includes starch (60-68%), protein (8-15%), fat, sugar, cellulose, minerals, and vitamins, making it a balanced food source for humans (Rani *et al.*, 2024) ^[13].

Globally, wheat is cultivated on about 220 million hectares with a record production of 763.06 million tonnes. The maximum area under wheat is in India (14%), followed by Russia (12.43%), China (11.14%), and the USA (6.90%), together accounting for nearly 45% of global wheat area. However, in terms of production, China ranks first with 136 million tonnes, followed by India (98.51 mt), Russia (85 mt), and the USA (47.35 mt). Approximately 58% of global wheat is produced by traditional wheat-growing countries such as China, India, Russia, the USA, Canada, Ukraine, and Pakistan (Bhatti *et al.*, 2023) ^[4]. In India, wheat is the second most important crop after rice and is mainly cultivated as a *rabi* crop, sown in November and harvested between March and April. The cultivated area under wheat has shown an increasing trend at the national level, rising from 29.04 mha to 30.54 mha, with a net gain of 1.5 mha (5%) (Bhatti *et al.*, 2023) ^[4]. Among the wheat-growing states, Uttar Pradesh has the largest share of 9.75 mha (32%), followed by Madhya Pradesh (18.75%), Punjab (11.48%), Rajasthan (9.74%), Haryana (8.36%), and Bihar (6.82%). The sharp rise in minimum support price and assured government procurement have been major drivers of this expansion (Bhatti *et al.*, 2023) ^[4].

Wheat is a C3, long-day plant that requires cool and moist weather during the vegetative phase and warm, dry weather during grain filling for optimum growth. The minimum, optimum and maximum cardinal temperatures for the germination of the wheat crop are 3 to 4.5 °C, 25 and 30-32 °C respectively. A mean daily temperature of 15 to 20 °C is the optimum for growth and

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development. Higher temperatures of about 30 to 35 °C generally have detrimental effects on growth. The optimal range of temperature for the germination of winter wheat and, for its vegetative growth is 15 to 20 °C (Mavi *et al.*, 2016) ^[11]. Like other crops, wheat responds positively to the application of both macronutrients (N, P, K, S) and micronutrients (Fe, Zn, Cu, Mn, B, Mo, Cl). Among these, nitrogen is most vital as it is a key constituent of amino acids, proteins, nucleic acids, enzymes, and chlorophyll, and its adequate supply ensures vigorous vegetative growth and deep green color (Ayub, 2007). Similarly, sulphur is critical for protein synthesis, amino acid (cysteine, methionine) formation, vitamin production, and chlorophyll development. The increasing deficiency of sulphur in Indian soils is mainly attributed to the continuous use of sulphur-free fertilizers and intensive cropping systems (Abbas *et al.*, 2020) ^[2]. Balanced sulphur application is therefore indispensable for improving yield and grain quality.

Although micronutrients are required in smaller quantities, they are as essential as macronutrients for enzymatic activities, photosynthesis, and reproductive development (Singh *et al.*, 2016) ^[15]. Hence, balanced nutrient management, involving the judicious use of nitrogen, sulphur, and micronutrients like iron and zinc, is essential not only for improving wheat yield and soil fertility but also for enhancing the nutritional quality of the grain. This integrated approach is vital to sustain wheat productivity and meet the challenges of food and nutritional security in the future (Abbas *et al.*, 2020; Alloway *et al.*, 2018) ^[2, 3].

Materials and Methods

The experiment was carried out during *rabi* season of 2024 at crop research farm of allahabad school of agriculture, Sam Higginbottom university of agriculture, technology and sciences, Prayagraj, which is located at 25° 24' 42" n latitude, 81° 50' 56" e longitude and 98 m altitude above the mean sea level. The experiment was conducted in randomized block design with 10 treatment each replicated thrice. The plot size of each treatment was 3m x 3m. The factors are Nitrogen (90 kg/ha, 120 kg/ha, 150 kg/ha) and Sulphur (20 kg/ha, 30 kg/ha, 40 kg/ha). The treatment combinations are T1. Nitrogen 90 kg/ha + Sulphur 20 kg/ha, T2. Nitrogen 90 kg/ha + Sulphur 30 kg/ha, T3. Nitrogen 90 kg/ha + Sulphur 40 kg/ha, T4. Nitrogen 120 kg/ha + Sulphur 20 kg/ha, T5. Nitrogen 120 kg/ha + Sulphur 30 kg/ha, T6. Nitrogen 120 kg/ha + Sulphur 40 kg/ha, T7. Nitrogen 150 kg/ha + Sulphur 20 kg/ha, T8. Nitrogen 150 kg/ha + Sulphur 30 kg/ha, T9. Nitrogen 150 kg/ha + Sulphur 40 kg/ha, T10. Control -120-60-40 kg -NPK/ha. The Wheat crop was sown on 16 Dec 2024. Harvesting was done by taking 1 m² area from each. And from it five plants were randomly selected for recording growth and yield parameters. The observations were recorded for plant height, maximum dry weight, higher number of effective tillers/plants, higher number of grains/spike, higher test weight, higher grain yield, higher straw yield and higher harvest index was recorded in treatment in treatment 9 (Nitrogen 150 kg/ha + Sulphur 40 kg/ha). The data was subjected to statistical analysis by analysis of variance method. Economics was calculated viz., cost of cultivation, gross return, net return, benefit cost ratio were calculated.

Result and Discussion

Plant Height (cm): From 20 DAS to 100 DAS, the wheat plant height was measured; the greatest plant height was recorded at 100 DAS. Among the treatments, the effects of nitrogen and sulphur

on plant height growth were noted. The maximum plant height (422.37 cm) was observed by (T9) at 100 DAS when 150 kg of nitrogen and 40 kg of sulfur were applied per hectare. Nevertheless, T1, T4, T5, T7, and T10 were statistically comparable to T9. 150 kg of nitrogen and 40 kg of sulfur per hectare.

Increased nitrogen levels, particularly at 100 kg/ha, were shown to significantly increase plant height. This might be because improved nitrogen absorption leads to greater protein synthesis, cell division, and elongation. Through stomatal control, chlorophyll synthesis, and enzymatic activation, sulfur administration also played a critical role. Muhammad *et al.* (2017) ^[10] and Dundgiala *et al.* (2021) ^[6] observed similar outcomes in wheat.

Plant dry weight (g/plant): Wheat plant dry weight was recorded from 20 to 100 DAS, with the maximum (23.55 g) observed at 100 DAS under treatment T9, which was significantly higher than most treatments but statistically at par with T6, T7, and T8. The increase in dry weight with 150 kg N/ha is attributed to enhanced growth and photosynthetic activity, leading to greater nutrient uptake and biomass accumulation, consistent with Jadon *et al.* (2015) ^[9]. Similarly, sulphur application at 40 kg/ha significantly improved dry weight due to its role in physiological and biochemical processes, corroborating the findings of Muhammad *et al.* (2017) ^[10].

Crop Growth Rate (g/m²/day)

Between 75-100 DAS, crop growth rate was statistically non-significant across treatments, with the highest value (0.77 g/m²/day) in T7 (150 kg N/ha + 20 kg S/ha). The higher growth rate under 150 kg N/ha may be due to improved light absorption, photosynthetic efficiency, and metabolic activity, consistent with Dubey *et al.* (2018) ^[5].

Relative Growth Rate (g/g/day)

During 75-100 DAS, relative growth rate was statistically non-significant, with the highest value (0.011 g/g/day) recorded in T7 (150 kg N/ha + 20 kg S/ha). Although some variation in relative growth rate was observed across treatments at different stages, the differences were not statistically significant. Maximum values tended to occur under higher nitrogen and sulphur doses, indicating a possible trend toward improved growth. These results align with earlier findings that nutrient application did not significantly influence relative growth rate.

Yield attributes and Yield

Number of effective tillers/m²

The maximum number of effective tillers/m² (13.59) was recorded in T9 (150 kg N/ha + 40 kg S/ha), which was significantly superior to all other treatments. However, T7 (150 kg N/ha + 20 kg S/ha) and T2 (150 kg N/ha + 30 kg S/ha) were statistically at par with T9. The higher tiller number under nitrogen application may be attributed to improved root development and nutrient uptake, while sulphur promotes enzyme activity related to tiller initiation. These results are consistent with the findings of Dubey *et al.* (2018) ^[5].

Number of Grains/spikes

The maximum number of grains/spike (47.6) was recorded in T9 (150 kg N/ha + 40 kg S/ha), which was significantly superior to all other treatments. However, T7 (150 kg N/ha + 20 kg S/ha) and T2 (150 kg N/ha + 30 kg S/ha) were statistically at par with

T9. The higher grains/spike under these treatments may be attributed to improved nitrogen uptake and efficient translocation of photosynthates to the spike during the grain filling stage. These results are in agreement with the findings of Saha *et al.* (2017)^[14] and Muhammad *et al.* (2017)^[10].

Test weight (g)

The maximum higher test weight (31.14 g) was recorded with T9 (Nitrogen 150 kg/ha + Sulphur 40 kg/ha) which was superior over all other treatments. These treatments were found to be non-significant. Higher test weight might be due to zinc-enhanced enzymatic activities involved in grain filling and accumulation of starch and protein. Similar results were also reported by Muhammad *et al.* (2017)^[10].

Grain yield (t/ha)

The maximum grain yield (4.49 t/ha) was obtained in T9 (150 kg N/ha + 40 kg S/ha), which was superior to all other treatments, though the differences were statistically non-significant. Wheat growth and productivity are highly sensitive to temperature variations, with specific cardinal temperature requirements at different growth stages. The minimum, optimum, and maximum cardinal temperatures for germination are reported to be 3-4.5 °C, 25 °C, and 30-32 °C, respectively (Porter & Gawith, 1999)^[12]. For overall growth and development, the optimum mean daily temperature is 15-20 °C (Asseng *et al.*, 2011)^[1]. Exposure to higher temperatures, particularly in the range of 30-35 °C, generally results in adverse effects such as accelerated phenological development, reduced

photosynthetic efficiency, and shortened grain filling duration (Tewolde *et al.*, 2006)^[17]. When mean daily temperatures exceed 25 °C during the vegetative stage, plant growth and tiller production decline, leading to reduced biomass accumulation. High temperatures beyond 30 °C, particularly when coinciding with low relative humidity at the maturity stage, cause forced maturity and result in significant yield reductions (Stone & Nicolas, 1994; Hakim *et al.*, 2012)^[16, 8].

Straw yield (t/ha)

The significantly higher straw yield (7.45 t/ha) was recorded in T9 (150 kg N/ha + 40 kg S/ha), which was superior to all other treatments, while T6, T7, and T8 were statistically at par with T9. Nitrogen contributes to leaf expansion and chlorophyll synthesis, while sulphur supports metabolic activities enhancing biomass production.

Harvest index (%)

The higher harvest index under T2 may be attributed to efficient partitioning of assimilates towards reproductive structures, leading to improved grain proportion relative to total biomass. However, non-significant differences suggest that while nutrient management influenced biomass allocation, other environmental factors also played a role.

Economic analysis: The Highest benefit cost ratio (2.01) was recorded in T9 (Nitrogen 150 kg/ha + Sulphur 40 kg/ha) as compared to other treatments.

Table 1: Influence of Nitrogen and Sulphur on growth and growth attributes of Wheat

S. No	Treatment Combinations	Plant height	Plant dry weight (g/plant)	Crop growth rate (g/m ² /day)	Relative growth rate (g/g/day)
1.	Nitrogen 90 kg/ha + Sulphur 20 kg/ha	405.70	23.21	0.51	0.006
2.	Nitrogen 90 kg/ha + Sulphur 30 kg/ha	380.43	22.53	0.22	0.003
3.	Nitrogen 90 kg/ha + Sulphur 40 kg/ha	384.90	22.00	0.20	0.003
4.	Nitrogen 120 kg/ha + Sulphur 20 kg/ha	410.37	20.90	0.24	0.003
5.	Nitrogen 120 kg/ha + Sulphur 30 kg/ha	405.10	20.81	0.40	0.006
6.	Nitrogen 120 kg/ha + Sulphur 40 kg/ha	395.97	21.38	0.57	0.008
7.	Nitrogen 150 kg/ha + Sulphur 20 kg/ha	409.70	22.67	0.77	0.011
8.	Nitrogen 150 kg/ha + Sulphur 30 kg/ha	384.17	22.00	0.40	0.005
9.	Nitrogen 150 kg/ha + Sulphur 40 kg/ha	422.37	23.55	0.44	0.006
10.	Control -120:60:40 kg NPK/ha	409.03	21.40	0.37	0.006
	F test	S	S	NS	NS
	S.Em±	13.94	0.72	0.19	0.002
	CD (p=0.05)	41.44	2.14	-	-

Table 2: Influence of Nitrogen and Sulphur on yield and yield attributes of Wheat

S. No	Treatment Combinations	Effective tillers/Plants	Number of grains/spike	Test weight (g)	Grain yield (t/ha)	Straw yield (kg/ha)	Harvest Index (%)
1.	Nitrogen 90 kg/ha + Sulphur 20 kg/ha	9.81	38.2	29.66	3.69	5.20	33.33
2.	Nitrogen 90 kg/ha + Sulphur 30 kg/ha	9.98	38.1	29.95	3.75	5.46	34.01
3.	Nitrogen 90 kg/ha + Sulphur 40 kg/ha	10.35	35.0	30.66	3.96	5.93	34.84
4.	Nitrogen 120 kg/ha + Sulphur 20 kg/ha	10.56	39.9	29.54	4.02	6.24	34.36
5.	Nitrogen 120 kg/ha + Sulphur 30 kg/ha	11.17	40.7	28.06	3.40	6.52	34.60
6.	Nitrogen 120 kg/ha + Sulphur 40 kg/ha	11.63	42.3	29.77	3.10	6.96	35.71
7.	Nitrogen 150 kg/ha + Sulphur 20 kg/ha	12.14	42.8	29.33	3.25	7.16	34.13
8.	Nitrogen 150 kg/ha + Sulphur 30 kg/ha	12.47	46.5	29.50	4.33	7.25	35.21
9.	Nitrogen 150 kg/ha + Sulphur 40 kg/ha	13.59	47.6	31.14	4.49	7.45	35.97
10.	Control -120:60:40 kg NPK/ha	9.23	38.0	28.31	3.47	4.30	31.25
	F test	S	S	NS	NS	S	NS
	S.Em±	0.53	1.96	0.76	0.38	0.30	0.001
	CD (p=0.05)	1.59	5.85	-	-	0.90	-

Table 3: Influence of Nitrogen and Sulphur on Economics of Wheat

S. No. Treatment Combinations	Total cost of cultivation	Gross Return	Net Return	B:C ratio
	(INR/ha)	(INR/ha)	(INR/ha)	
1. Nitrogen 90 kg/ha + Sulphur 20 kg/ha	46083.79	109340.00	63256.21	1.37
2. Nitrogen 90 kg/ha + Sulphur 30 kg/ha	47901.97	113577.15	65675.18	1.38
3. Nitrogen 90 kg/ha + Sulphur 40 kg/ha	49720.15	119517.5	69797.35	1.40
4. Nitrogen 120 kg/ha + Sulphur 20 kg/ha	46871.29	122883.00	76011.71	1.62
5. Nitrogen 120 kg/ha + Sulphur 30 kg/ha	48689.47	126032.50	77343.03	1.58
6. Nitrogen 120 kg/ha + Sulphur 40 kg/ha	50507.65	130241.75	79734.10	1.58
7. Nitrogen 150 kg/ha + Sulphur 20 kg/ha	47658.79	133910.00	86251.21	1.80
8. Nitrogen 150 kg/ha + Sulphur 30 kg/ha	49476.97	139620.50	89843.53	1.81
9. Nitrogen 150 kg/ha + Sulphur 40 kg/ha	51295.15	154405.00	103109.85	2.01
10. Control -120:60:40 kg NPK/ha	40206.52	101981.25	61775.25	1.51

Conclusion

The combined application of nitrogen and sulphur significantly improved wheat growth, yield components, and biomass, with 150 kg N/ha + 40 kg S/ha (T9) producing the highest grain and straw yield. Harvest index was less affected, indicating that total biomass rather than its partitioning. Despite nutrient management primarily enhanced optimum nutrient application, high temperatures above 30 °C during reproductive and grain filling stages negatively impacted wheat productivity. Therefore, integrating proper nutrient management with climate-resilient practices is essential to achieve sustainable wheat yields under heat stress conditions.

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