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EFFECT OF DIFFERENT CONCENTRATIONS OF SULPHUR ON THE GROWTH ECONOMIC YIELD OF THREE CHICKPEA (*CICER ARIETINUM)* VARIETIES

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ABSTRACT

Sulphur (S) is an important macronutrient for growth in animals, plants, microbes, and people. Sulphur shortage in plants leads to decreased photosynthetic activity, poor nitrogen metabolism and protein synthesis, low oil percentage, dwarfism, and growth retardation. The consequences are more severe in shoots than roots. Symptoms of S shortage in plants include the yellowing of immature leaves, chlorosis, necrosis in the late stages of development, spindles with short stalks, and poor crop production. A field experiment examined the effects of sulphur on the development and productivity of chickpeas (*Cicer arietinum* L.), The world's most nutritious pulse crop. In the University of Agriculture Faisalabad, Pakistan undertook the study to investigate the effects of different sulphur concentrations on the economic yield of three different types of chickpeas (Noor-19, Bittal-21, and Bittal-16). The experiment involved two factors: the kind of chickpeas and the amount of sulphur (120 mg and 240 mg) applied during the blooming period. The study found that 240 mg of sulphur significantly increased grain yield, seed index (1000 grain weight), pod count plant^{-1}, branch number plant^{-1}, and plant height compared to the control. Higher sulphur levels produce a positive reaction because sulphur improves photosynthetic efficiency, protein synthesis, and nitrogen fixation, all of which boost yield and biomass accumulation. Other metrics, such as root length and chlorophyll b and c content, did not respond significantly to sulphur treatment, presumably due to limited mobility or assimilation of sulphur beyond specific metabolic requirements in chickpea growth. Therefore, adding the proper sulphur treatment to chickpea cropping systems' fertilization program can improve crop yield.

Keywords: chickpea, economic yield, sulphur, varieties

INTRODUCTION

Chickpea, technically known as *Cicer arietinum*, is a member of the *Fabaceae* family, sometimes known as the legume, pea, or bean family. The *Fabaceae* family, which includes peas, beans, lentils, soybeans, peanuts, and clover, is one of the largest and most commercially significant plant groups (Singh *et al.,* 2022). Chickpeas are annual leguminous plants grown for their edible seeds, which are also known as chickpeas or garbanzo beans. Legumes are significant food crops (Jimenez-Lopez *et al.,* 2020). It is a widespread family cultivated over 130 million hectares globally. Legumes possess significant amounts of fiber, energy, and protein, contributing to roughly 1/3rd of the dietary protein and processed vegetable oil consumption in humans (Kumar *et al.,* 2022b). Beans, lentils, and chickpeas are just a few examples of the necessary proteins and amino acids found in legumes. They also include trace elements and minerals like potassium, calcium, phosphorus, and vitamins D, B_1, B_2, A, C and PP (Roorkiwal *et al.,* 2021). These nutrients are essential for maintaining healthy bones, working muscles, and controlling fluids. Legumes benefit from a healthy, balanced diet since they promote overall well-being (Tripathi, 2024). *Cicer arietinum* is known by various names in many countries, including chana (Hindi) and gramme or Bengal gramme (English). It is also known as 'nakhut' or 'nohut' in several places worldwide (Turkey, Romania, Bulgaria, and Afghanistan). Chickpeas are cultivated in around fifty-seven countries worldwide under varying environmental conditions (Koul *et al.,* 2022).

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With 80% of the regional contribution, South and Southeast Asia lead in chickpea production. Although affluent nations contribute little to chickpea production, yields in several Eastern European countries are notably high. China likewise had a high production level of 4,537 kg ha^{-1} from 2013 to 2017 (Fikre *et al.,* 2020). Chickpeas are abundant in iron, zinc, magnesium, and calcium. A 100g serving of chickpeas can fulfill the daily iron and zinc requirements, while a 200g serving can fulfill the daily magnesium requirement. Two types of chickpeas are cultivated globally: desi and Kabuli (Zhang *et al.,* 2024). Kabuli chickpeas are characterized by large, cream-colored seeds with thin seed coats, while Desi has smaller brown seeds with thick seed coats. Chickpea varieties include Desi and Kabuli. In South Asia, chickpeas are commonly used in dal, although it is popular in many areas worldwide (Yegrem, 2021).

Kabuli varieties are characterized by their tall stature, large cream or beige-colored seeds, and white flowers. Desi varieties exhibit reduced height and smaller leaflets, pods, and seeds (Eker *et al.,* 2022). The blooms primarily exhibit a pink coloration. Desi types exhibit more significant variability in the color of their seed, pod, flower, and vegetative components, as well as in the shape and surface characteristics of their seeds, compared to Kabuli types. The Kabuli chickpea is believed to have originated from desi varieties (Kenea and Mohammed, 2023). Chlorosis is a severe condition that affects plants, causing yellowing, passing away, and disappearance (Hossain *et al.,* 2021). It is a significant barrier to sustainable agricultural production in Asia due to high-yielding crop types, sulphur-free fertilizers, irrigation water misuse, low atmospheric sulphur deposition, winter rainfall, and acid soils (Gerson and Hinckley, 2023). Sulphur is essential for plant growth, photosynthesis, respiration, and nitrogen fixation. Insufficient sulphur availability can hinder plant growth, seed maturation, and productivity. Optimal sulphur levels during vegetative growth and canopy formation can increase photosynthetic surface area, enabling the synthesis of carbohydrates and allocation to seed development (Mustafa *et al.,* 2022).

Optimal sulphur levels can also impact plant reproduction, such as pollen development, pollination, and fertilization (Beltrán *et al.,* 2023). A sulphur deficiency can lead to decreased pollen viability, hindering pollination and reducing seed output. The harvest index of chickpeas can be increased through the adequate supplementation of sulphur and other essential nutrients (Mekonnen, 2018). Soil testing and nutrient management techniques are employed to assess sulphur requirements for optimal growth, enabling the application of appropriate fertilizers (Ullah *et al.,* 2020). The objective of this research is to identify the best sulphur concentration for optimizing the economic output of three chickpea cultivars. It will look at sulphur's effect on growth, nutrient absorption, and yield quality parameters such as protein content. The study will identify those that are most sensitive to sulphur by comparing varietal responses. Finally, it aims to find sulphur application recommendations for sustainable chickpea production.

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted during the rabi season of 2022-2023 at the University of Agriculture, Faisalabad, using sandy clay pots with a diameter of 16cm, each filled with 8 kg of soil. Seeds of chickpea (*Cicer arietinum*) varieties Bittal-2021, Noor-2019, and Bittal-2016 were procured from the Ayub Agriculture Research Institute in Faisalabad, Pakistan. The experiment incorporated eighteen treatment combinations, involving two sulphur levels (120mg and 240mg) arranged in a split-plot design, with three replications for each treatment.

Planting and treatment application

Seeds were sown at a depth of 8cm in the pots, with a plant-to-plant spacing of 10cm and an inter-row spacing of 30cm. After germination, seedlings were thinned to five uniform individuals pot^{-1}. Flowering occurred approximately two months after germination when sulphur fertilizers at the specified levels (120mg and 240mg) were applied to the respective treatments.

Weather

Weather data were recorded from September to April to correlate environmental conditions with chickpea growth and yield. The average temperatures during this period ranged from 28-34°C in September, decreasing to 8-18°C in January, and then increasing to 20-30°C by April. These temperature fluctuations significantly influenced the growth dynamics and development of the chickpea plants.

Harvesting

The chickpea plants were harvested at physiological maturity, and the yield parameters were recorded. The study adhered to a completely randomized design (CRD) to mitigate experimental error, with each treatment replicated thrice.

Data Collection

The investigation evaluated various growth, yield, and economic parameters of the chickpea plants, including:

Root fresh weight (RFW) in grams
Shoot dry weight (SDW) in grams
Root dry weight (RDW) in grams
Shoot fresh weight (SFW) in grams
Plant height (PH) in centimeters
Root length (RL) in centimeters
Shoot length (SL) in centimeters
No. of nodules
No. of pod
100-seed weight (100 SWT) in grams
Economic parameters
Harvest index
Biological yield
Chlorophyll a, b, and c

Statistical analysis

Statistical methods were employed to compare treatment means, with a significance level set at 5%. Analysis of Variance (ANOVA) was conducted, followed by Tukey's Honest Significant Difference (HSD) test for post-hoc comparisons.

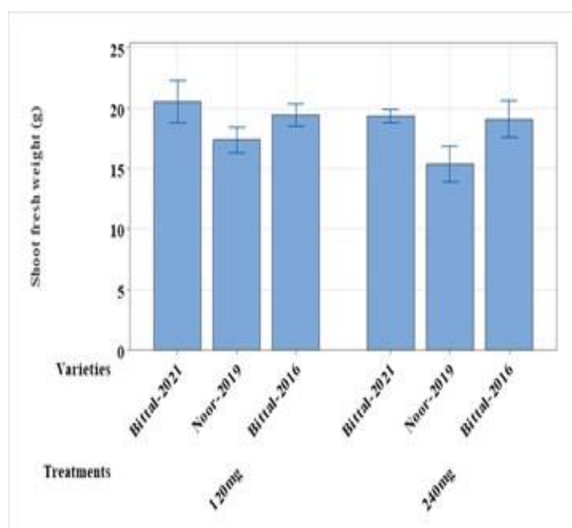
Growth Attributes

Fresh, dry weights of roots and shoots (g)

Three chickpea varieties (Bittal-2021, Noor-2019, and Bittal-2016) investigated regarding fresh shoot weight (g) under sulphur treatments of 120mg and 240mg. The sulphur treatments had no significant effect on the results, but the maximum fresh shoot weight was found in a 120mg sulphur application (19.0g), and the minimum (17.9g) present at 240mg. Varieties showed a significant effect; the maximum fresh shoot weight was present in Bittle-2021 (19.9g), and the minimum was Noor-2019 **(**16.3g). The sulphur treatments had no significant effect on the results, but the maximum root fresh weight was found in a 120mg sulphur application, which was (2.82g), and the minimum was (1.38g) which was present at 240mg. Varieties showed a significant effect; the maximum root fresh weight was present in Noor-2019 (2.07g), and the minimum was Bittle-2016 (1.27g) as mentioned in (Table 1). The sulphur treatments had no significant effect on the results, but the maximum shoot dry weight was found in a 240mg sulphur application, which was (4.04g), and the minimum was (4.02g) which was present at 120mg. Varieties didn't show a significant effect; the maximum shoot dry weight was present in Bittal-2021 (4.48g), and the minimum was in Bittal-2016 (3.7g). The treatments had no significant effect on the results. Still, the maximum root dry weight was found in 120mg, which was (0.27g), and the minimum was present at 240mg, which was (0.26g), and those varieties also showed no significant effect. The maximum root dry weight was present in Bittal-2021 (0.42g), and the minimum was in Bittal-2016 (0.16g) as shown in Figure 1.

Table 1. Parameters of Shoot Fresh weight (g), Root fresh weight (g), Shoot dry weight (g), and Root dry weight (g)

Shoot Fresh weight (g)				
Treatments	**Bittle-2021**	**Noor-2019**	**Bittle-2016**	**Means**
120mg	20.5a	17.3a	19.4a	19.0a
240mg	19.3a	15.4a	19.1a	17.9a
Means	19.9	16.3	19.2	-
Root fresh weight (g)				
Treatments	Bittle-2021	Noor-2019	Bittle-2016	Means
120mg	1.61a	1.42ab	1.21b	2.82 ab
240mg	1.49ab	1.31ab	1.34ab	1.38 ab
Means	1.55	2.07ab	1.27b	-
Shoot dry weight (g)				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	3.9ab	4.27ab	3.9ab	4.02ab
240mg	5.07a	3.57b	3.5b	4.04b
Means	4.48	3.92b	3.7b	
Root dry weight (g)				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	0.44a	0.27a	0.12a	0.27a
240mg	0.39a	0.193a	0.21a	0.26a
Means	0.42	0.231	0.16	-



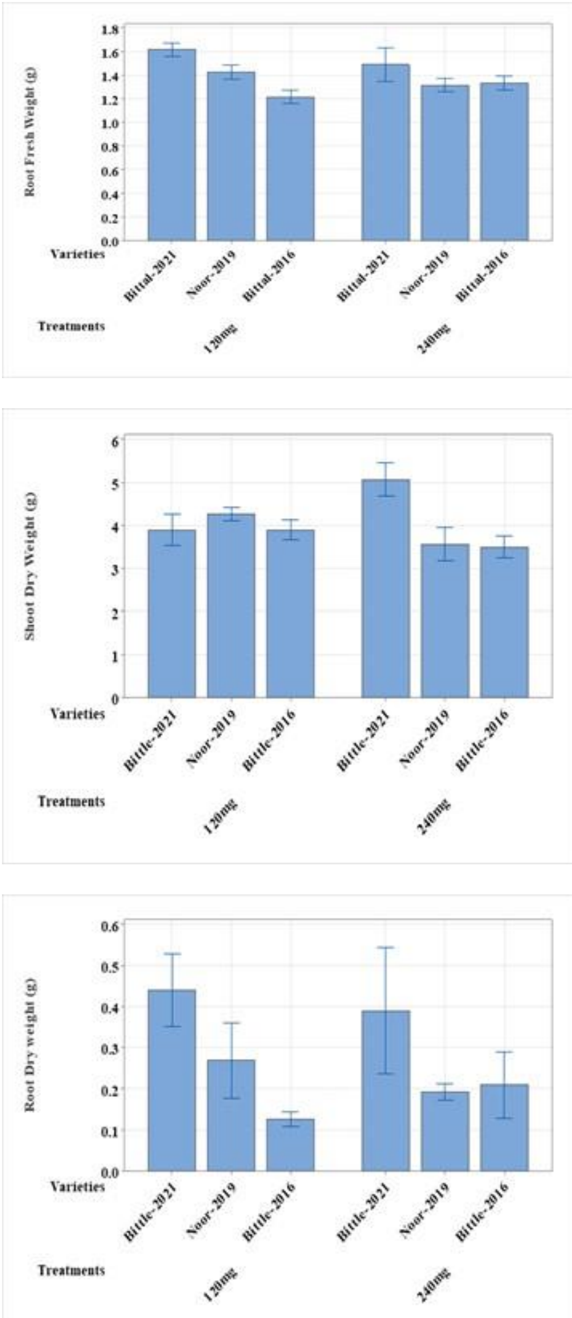


Figure 1. Comparisons of Shoot Fresh weight (g), Root fresh weight (g), Shoot dry weight (g), and Root dry weight (g)

Plant height (cm), No. of Branches Plant^{-1}, Shoot length (cm), and Root length (cm)

The height of chickpea plants varies based on cultivar, growing environment, and management techniques. Mature plants can reach 20-60cm (8-24 inches), while early growth has a compact, bushy appearance. Plant height affects crop management practices like trimming (Yadav *et al.,* 2022). Three chickpea varieties were examined under sulphur treatments, finding no significant effect on height. Noor-2019 had the highest plant height at 48.35cm. The branches plant^{-1} statistic measures the branching structure of chickpea plants, allowing researchers and farmers to determine optimal plant growth. Three chickpea varieties (Bittal-2021, Noor-2019, and Bittal-2016) showed no significant effect of sulphur treatments on branch count. However, Noor-2019 had the highest branch count, while Bittal-2016 had the lowest as shown in Figure 2. The interaction between varieties and treatment also lacked a significant effect. Shoot length is crucial for chickpea plant growth and development, affecting biomass accumulation, nutrient intake, and photosynthetic capability (Benali *et al.,* 2023). Root length is an essential indicator of plant growth and development, impacting nutrition, water intake, anchoring, and health. It is crucial for agriculture, ecology, horticulture, and plant physiology (Kumar *et al.,* 2022a).

The three chickpea varieties under sulphur treatments found significant effects on root length. The maximum root length was 240mg, while the maximum was in Bittal-2021. The interaction between varieties and treatment had no significant effect. Shoot lengths under 120 mg and 240 mg treatments found no significant impact on results as mentioned in (Table 2). Three chickpea varieties (Bittal-2021, Noor-2019, and Bittal-2016) showed no significant effect on shoot length, and the interaction between varieties and treatment had no significant impact.

Table 2. Parameters of plant height (cm), No. of branches plant^{-1}, Shoot length (cm), and Root length (cm)

Plant height (cm)				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	42.87abc	47.67ab	40.17bc	43.57a
240mg	43.3abc	49.03a	38.c	43.6a
Means	43.08b	48.35	39.43b	
No. of Branches Plant^{-1}				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	5.07a	4.37a	3.80a	4.38a
240mg	4.37a	4.30a	3.90a	4.19a
Means	4.72a	4.34a	3.85a	
Shoot length (cm)				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	35.0a	35.8a	33.13a	34.6a
240mg	37.06a	36.8a	33.4a	35.7a
Means	36.03	36.3	33.2	
Root length (cm)				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	16.76ab	15.8ab	13.7b	15.42ab
240mg	19.9a	18.1ab	15.37ab	17.79ab
Means	18.33	16.9ab	14.53b	

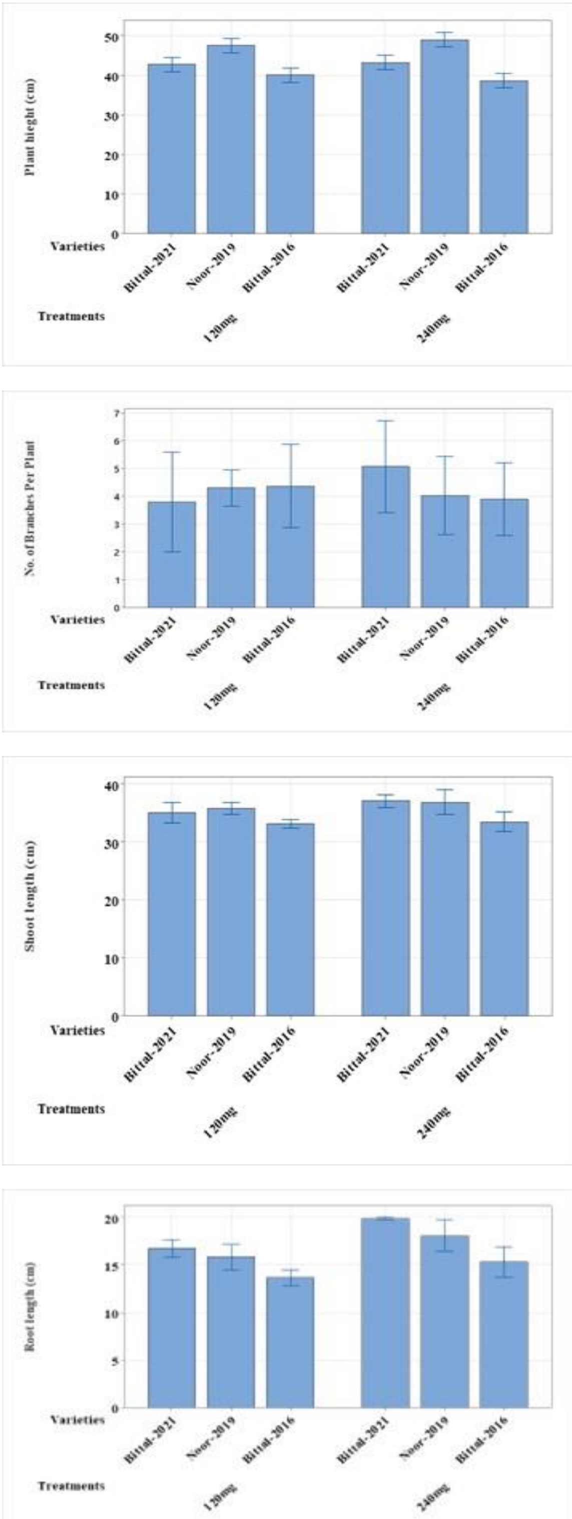


Figure 2. Comparisons of plant height (cm), No. of branches plant^{-1}, Shoot length (cm), and Root length (cm)

Nodulation

The study examined how three chickpea varieties (Bittal-2021, Noor-2019, and Bittal-2016) performed regarding nodules plant^{-1} under sulphur treatments of 120 and 240mg as mentioned in (Table 3.) The sulphur treatments had a significant effect on the results; the maximum number of nodules plant^{-1} (16) was found at the rate of 240mg, and the minimum (11) was with the application of sulphur at the rate of 120mg. The varieties showed a significant effect on no nodules plant^{-1}, as the maximum value was present in Noor-2019 (15), and the minimum was Bittal-2016 (10) as shown in Figure 3.

Table 3. Parameters of no nodules plant^{-1}

No. of Nodules Plant^{-1}				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	13ab	13ab	9b	11b
240mg	18a	17a	12b	16a
Means	15	15b	10b	

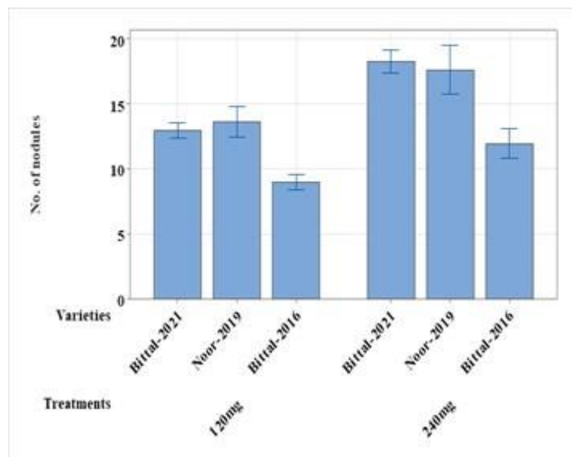


Figure 3. Comparisons of No. of Nodules Plant^{-1}

Yield attributes

No pods Plant^{-1}, No. of seeds Plant^{-1} and 100 seed weight (g)

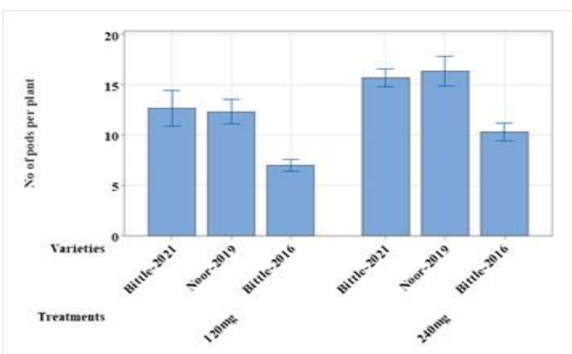
The sulphur treatments significantly affected the results, with the maximum pods plant^{-1} found at 240mg and the minimum at 120mg. The productivity and output potential of chickpea plants are determined by the number of seeds plant^{-1}, which is influenced by factors like variety, environmental conditions, cultural practices, and management strategies. A higher seed count indicates better plant health, efficient pollination, and effective seed germination, increasing grain output and crop productivity (Bhuriya *et al.,* 2023). The table shows the findings of a study that investigated the effects of two treatment doses (120mg and 240mg) on three crop varieties: Bittal-2021, Noor-2019, and Bittal-2016. The data display the mean values of 100-

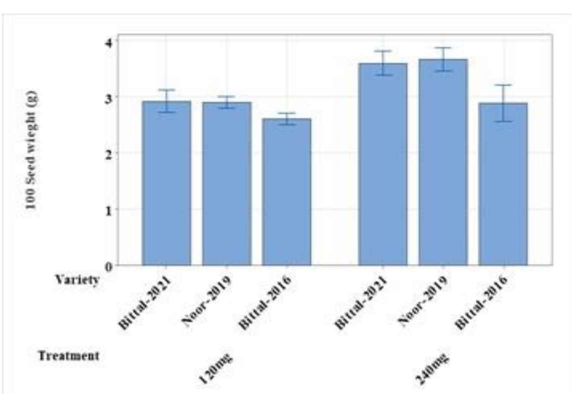
seed weight (g) for each treatment-variety combination, as well as the overall means for each treatment and variety. The 120mg treatment (T_1) results in an average seed weight of 2.81g across the three types, with Bittal-2021 and Noor-2019 yielding considerably greater weights (2.92g and 2.91g, respectively) than Bittal-2016 (2.61g), indicated as "B" in the grouping.

240mg treatment (T_2) produces a larger overall mean (3.39g) than 120mg, with the greatest mean of 3.67g in Noor-2019 and 3.60g in Bittal-2021. Bittal-2016 under 240mg (2.89g) showed a lesser increase, as written in Figure 4.

Table 4. Parameters of no pods plant^{-1}, No. of seeds plant^{-1} and 100-Seed weight (g)

No of Pods Plant^{-1}				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	12abc	12abc	10bc	11b
240mg	15ab	16a	7c	13a
Means	13	14	8b	
No. of seeds Plant^{-1}				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	14abc	12abc	12c	12ab
240mg	16a	16a	12bc	15a
Means	15	14	12b	
100 seed weight (g)				
Treatments	Bittal-2021	Noor-2019	Bittal-2016	Means
120mg	2.92ab	2.91 ab	2.61b	2.81ab
240mg	3.60a	3.67 a	2.89ab	3.39a
Means	3.26	3.29	2.71b	





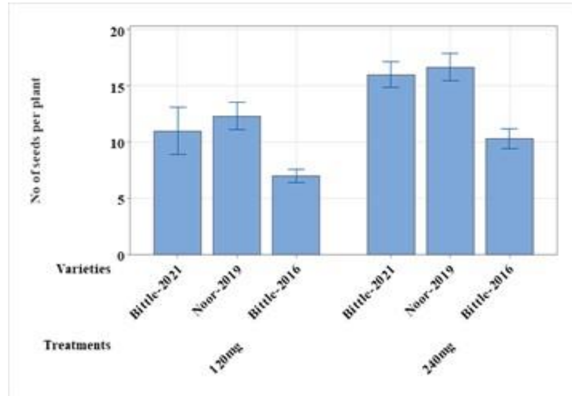


Figure 4. Comparisons of no pods Plant^{-1}, No. of seeds Plant^{-1} and 100 seed

Economic yield (kg/ha), Biological yield (%) and Harvest index (HI)

The sulphur treatments had a considerable effect on yield outcomes. The highest economic yield, measured in kg ha^{-1}, was observed at 240 mg S (28.17 kg ha^{-1}), and the lowest at 120mg S (24.52 kg ha^{-1}). Economic yield varied with variety, with Noor-2019 reaching the highest figure (30.05 kg ha^{-1}) and Bittal-2016 the lowest (16.03 kg ha^{-1}). Figure 4 shows that the harvest index (HI), expressed as a percentage, was highest at 240mg S (22.42) and lowest at 120 mg S (15.64%). Table 5 shows that Noor-2019 had the greatest HI (20.76%) and Bittal-2016 had the lowest (15.71%) among the tested types, as mentioned in (Table 5). The biological yield, the total biomass produced by a crop or plant population, is influenced by genetics, environment, production methods, and management strategies. (Bailey-Serres *et al.,* 2019). The greatest biological yield at 240mg S was 32.76 kg ha^{-1}, whereas the lowest was at 120mg S (28.7 kg ha^{-1}). The interaction between variety and sulphur treatments had no significant effects, as shown in Figure 5.

Table 5. Parameters of Economic Yield, Biological yield, and Harvest Index

Economic Yield				
Treatment	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	17.34b	27.49a	14.37b	24.52b
240mg	34.22a	32.60a	17.70b	28.17a
Means	25.78	30.05	16.03b	
Biological yield				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	31	31.70b	23.34c	28.7b
240mg	31b	36.53a	30.67b	32.76a
Means	31b	34.11	26.99b	
Harvest Index				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	1634.26b	1592.95b	1465.87b	1,564.21b
240mg	2492.92a	2559.20a	1675.55b	2,242.55a
Means	1254.63	2076.075	1570.71b	

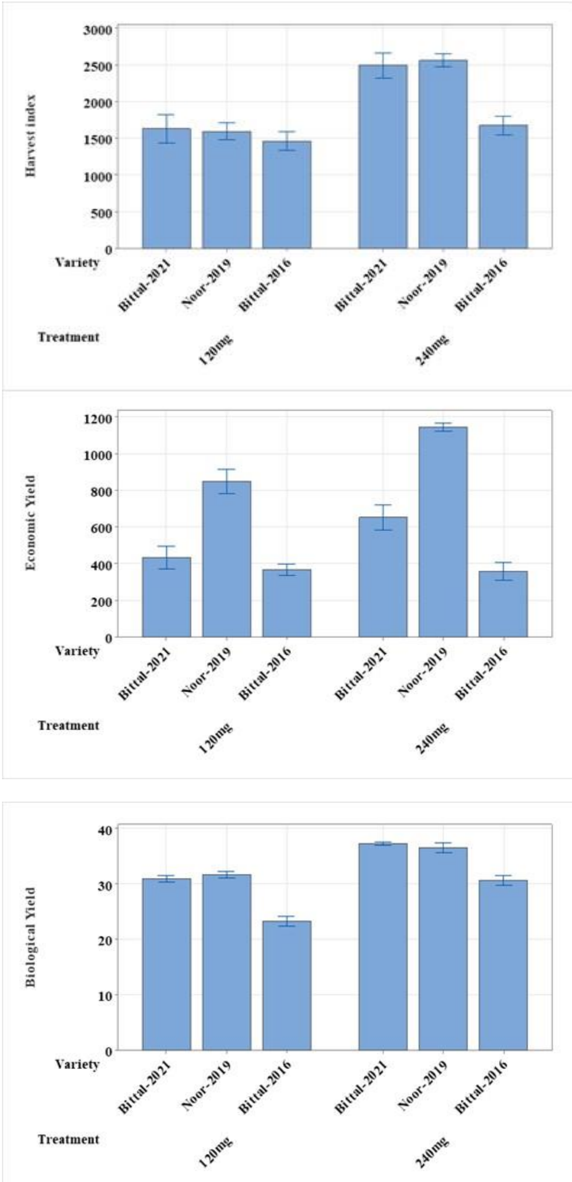
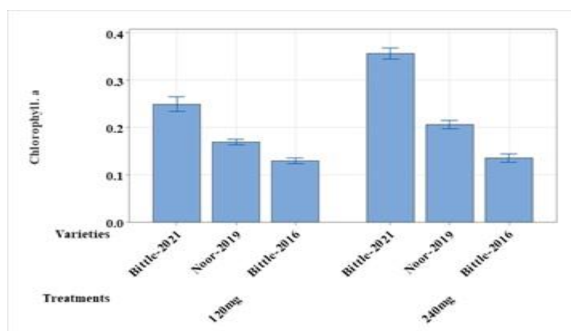


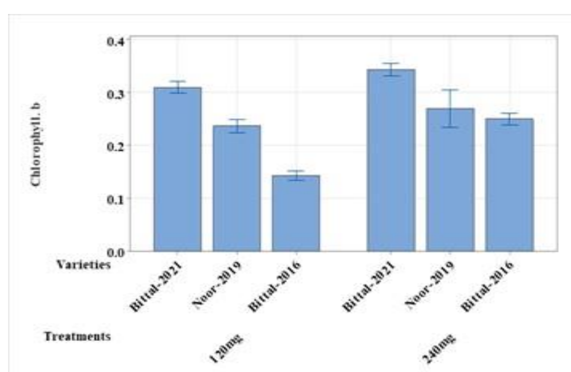
Figure 5. Comparisons of economic yield, biological yield, and Harvest index

Chlorophyll a, b, and c

The advantages of chlorophyll on chickpea productivity can be influenced by elements such as genetic features, environmental circumstances, nutrient availability, and crop management techniques. Sulphur and its levels were significantly affected by chlorophyll a (Maphosa *et al.,* 2020). The sulphur treatments had a highly significant effect on the results; the maximum chlorophyll a found in 240mg, which was (0.23), and the minimum was present in 120mg, which was (0.18). The varieties also showed a significant effect on chlorophyll a, as the maximum value was present in Bittal-2021 (0.30), and the minimum was in Bittal-2016 (0.13).

Chickpea varieties (Bittal-2021, Noor-2019, and Bittal-2016) were performed in terms of chlorophyll b under sulphur treatments of 120mg and 240mg. The sulphur treatments had a highly significant effect on the results; the maximum chlorophyll b was found in 240mg (0.28), and the minimum was present in 120mg (0.23) as mentioned in (Table 6). The varieties also significantly affected chlorophyll b; the maximum value was present in Bittal-2021 (0.32), and the minimum was in Bittal-2016 (0.19) as mentioned in Figure 5. The data show how different sulphur treatments (120mg and 240mg) affect carotenoid concentration in three varieties: Bittal-2021, Noor-2019, and Bittal-2016. Bittal-2021 had the highest carotenoid concentration of both treatments, with an average of 0.35. This suggests that this cultivar benefits the most from the treated sulphur, likely increasing carotenoid production. Noor-2019 had a moderate reaction, with an average carotenoid content of 0.31. This indicates a consistent increase in response to sulphur treatment, though not as pronounced as Bittal-2021. Bittal-2016 had the lowest carotenoid concentration (0.26 on average), indicating that it may be less susceptible to sulfur application than the other types, as shown in Figure 6.





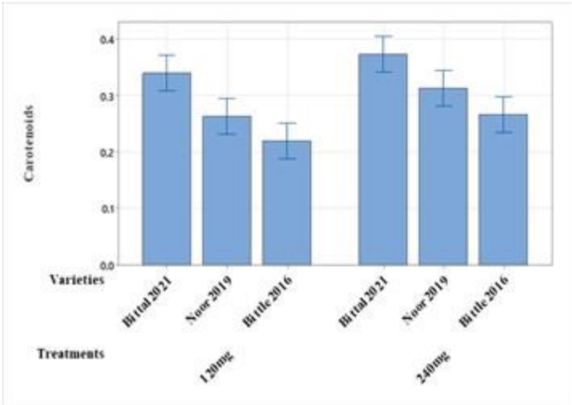


Figure 5. Comparisons of chlorophyll a, b and c

Table 6. Parameters of chlorophyll a, Chlorophyll b and Carotenoids

Chlorophyll a				
Treatments	**Bittal-2021**	**Noor-2019**	**Noor-2019**	**Means**
120mg	0.25b	0.17cd	0.13d	0.18a
240mg	0.35a	0.20bc	0.137d	0.23b
Means	0.30	0.18b	0.13c	
Chlorophyll b				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	0.31ab	0.23b	0.14c	0.23b
240mg	0.34a	0.27ab	0.27b	0.28a
Means	0.32	0.25b	0.19c	
Carotenoids				
Treatments	**Bittal-2021**	**Noor-2019**	**Bittal-2016**	**Means**
120mg	0.34ab	0.31bc	0.26cd	0.30
240mg	0.37a	0.31bc	0.27c	0.32
Means	0.35	0.31b	0.26c	

DISCUSSION

Three different varieties of chickpeas (Bittal-2021, Noor-2019, and Bittal-2016) were treated with sulphur, and the results show how complicated plant reactions are to nutrient applications. The discovery that a 120mg sulphur treatment produced the highest fresh shoot weight supports a threshold effect, whereby lower dosages may result in optimal growth conditions without producing nutritional toxicity, as documented in previous studies (Nawaz *et al.,* 2017). On the other hand, possible overfertilization may have caused osmotic stress, which would have a detrimental effect on water intake and general plant health, as evidenced by the drop in fresh weight at the 240mg dosage (Koul *et al.,* 2022). Variations in root fresh and dry weight across treatments indicate changes in the plants' capacity to obtain nutrients and water. The increased root weight at 120mg sulphur may improve nutrient absorption efficiency, consistent with findings from a prior study that highlights the need for a balanced nutrient supply for root growth (Kodavali and Khurana, 2022). The highest number of seeds plant^{-1} was detected at 240mg 15 and the lowest at 120mg (12). The sulphur treatments had a significant influence on the results. Furthermore, the variety had a significant influence on the weight of the seeds; in Bittal-2021, the highest value was (15). The data analysis of sulphur 120mg revealed no significant effect of sulphur administration on the chickpea plant growth population. When S_2, 240mg was applied, plant height increased significantly, as did the number of branches, nodules, and pods plant^{-1}. Sulphur may contribute to accelerated vegetative growth by creating disulphide linkages, which are associated with protoplasm structural properties (Abuelsoud *et al.,* 2016). Higher sulphur doses may be the reason for the rise in sulphur content reported in chickpea seeds and straws. More nutrient absorption is the outcome of more nutrients mixed with higher seed and stover production (Hadole *et al.,* 2024). Adding sulphur to chickpea seeds has been demonstrated to boost protein content and yield. Higher sulphur dosages have been demonstrated in studies to boost root activity and nitrogen-sulphur translocation, resulting in the synthesis of more sulphur-containing amino acids. This synergistic activity boosts nitrogen, sulphur, and protein levels in the soil. Sulphur also plays a direct role in the creation of chlorophyll in chickpea leaves, which speeds up photosynthesis and keeps chlorophyll levels high. These findings are consistent with earlier research (Gawhale *et al.,* 2024).

CONCLUSION

It can be concluded that chickpea plant growth and yield indices significantly improved when sulphur treatment rates were raised. The 240mg of sulphur applied to each plant resulted in a considerable increase in seed yield through the modulation of metabolic and enzymatic processes, including respiration and photosynthesis. Additionally, co-enzymes, photolytic enzymes, and glucose metabolism were affected by this therapy. Sulphur's bioactivity is thought to have increased the overall output and features of chickpea production; this suggests that 240mg of sulphur plant^{-1} can maximize the development and production of chickpeas.

AUTHOR’S CONTRIBUTION

N. Ameen: Correspondence, Writing and Data analysis.

T. Noor: Formatting and contextualizing the findings in the introduction.

S. Amjad: Literature review and revised the manuscript.
R. M. Akhtar: Measurement of morphological and yield traits of chickpea varieties.
B. Khan: Contributed to the interpretation of experimental results.

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