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Fffect of Sulpher Application on Performance of Fiber Yield Difference Jute Varieties

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ABSTRACT

Jute, a cornerstone of Nepal's agro-economy known as the "golden fiber," has faced a catastrophic decline in cultivated area and productivity. This decline is largely driven by degraded soil fertility in the intensive growing belts of the Terai region. Among essential nutrients, sulfur (S) has been identified as a critical limiting factor. Sulfur is vital for jute's unique physiology, directly influencing the biosynthesis of fiber-strengthening compounds and lignin-cellulose metabolism. The objective of this study was to determine the optimal sulfur application rate for maximizing the growth, fiber yield, and quality of commercially important jute varieties. A two-year field experiment (2022–2023) was conducted at the Jute Research Program, Itahari, to evaluate the effects of graded sulfur application (0, 10, 20, 30, and 40 kg S ha^{-1}) on growth, yield, and fiber quality of four commercially grown jute varieties (Itahari-4, JRO-204, NJ-7010, Itahari-2). The experiment was arranged in a split-plot design with three replications. Observations included plant height, basal stem diameter, green plant yield, green fiber yield, dry fiber yield, dry stick yield, and fiber thickness. The experimental results indicated that there were no significant differences in basal diameter and fiber thickness traits across the tested combinations. These traits remained largely unaffected by sulfur, suggesting genotypic stability. However, sulfur application significantly enhanced plant height, green fiber yield, dry fiber yield, green stick yield and dry stick yield in the 30 kg S ha^{-1} dose producing the highest overall performance across most traits. Among varieties, NJ-7010 (Rani) consistently exhibited superior growth and yield, particularly under optimal sulfur nutrition. The study concluded that 30 kg S ha^{-1} is the optimal sulfur dose for improving jute productivity and fiber quality under Nepalese Terai conditions, and integrating responsive varieties with balanced sulfur fertilization could provide a cost-effective strategy to revitalize the declining jute sector.

Keywords: Fiber, Jute, Sulphur, Yield

सारांश

जुट, नेपालको कृषि अर्थतन्त्रको मेरुदण्डका रूपमा परिचित “सुनौलो रेशा” बाली, पछिल्ला वर्षहरूमा खेती क्षेत्रफल र उत्पादकत्वमा गम्भीर तथा विनाशकारी गिरावट भोगिरहेको छ। यो गिरावट मुख्यतः तराई क्षेत्रका प्रमुख जुट खेती हुने भू—भागमा माटोको उर्वराशक्ति ह्रासका कारण देखिएको हो। अत्यावश्यक पोषक तत्त्वहरूमध्ये, सल्फर लाई जुट उत्पादनमा प्रमुख सीमितकारी तत्त्वका रूपमा पहिचान गरिएको छ। सल्फर जुटको विशिष्ट जैविक प्रक्रियाका लागि अत्यन्त महत्त्वपूर्ण हुन्छ, जसले रेशाको बल वृद्धि गर्ने यौगिकहरूको जैव संश्लेषण तथा लिग्निन—सेलुलोज चयापचयलाई प्रत्यक्ष रूपमा प्रभावित गर्दछ। यस अध्ययनको मुख्य उद्देश्य व्यावसायिक रूपमा महत्त्वपूर्ण जुटका प्रजातिहरूको वृद्धि, रेशा उत्पादन, र गुणस्तर अधिकतम बनाउनका लागि सल्फर प्रयोगको उपयुक्त मात्रा निर्धारण गर्नु रहेको थियो। उक्त उद्देश्य पूरा गर्नका लागि २०२२ र २०२३ मा लगातार दुई वर्ष जुटबाली अनुसन्धान कार्यक्रम, इटहरीमा परीक्षण गरिएको थियो। परीक्षणमा ० १०, २०, ३० र ४० के.जी. प्रति हेक्टर सल्फरको प्रभाव चार व्यावसायिक जुट प्रजातिहरू (इटहरी -४, जे आर ओ -२०४, एन जे —७०१० (रानी), इटहरी -२) मा मूल्याङ्कन गरिएको थियो। प्रयोगलाई तीन पुनरावृत्ति सहित स्प्रिट प्लट डिजायनमा परिक्षण संचालन गरिएको थियो। अध्ययनमा बिरुवाको उचाइ, तल्लो काण्डको मोटाइ, हरियो तथा सुख्खा स्टिक उत्पादन, हरियो तथा सुख्खा रेशा उत्पादन, रेशा मोटाइ जस्ता सूचकहरू अवलोकन गरिएको थियो। परिणामहरूले तल्लो काण्डको मोटाइ र रेशा मोटाइका विशेषताहरूमा सल्फर मात्राको प्रभाव नपरेको देखाए, जसले यी गुणहरू प्रजातिगत रूपमा स्थिर रहेको संकेत गर्दछ। तर, सल्फर प्रयोगले बिरुवाको उचाइ, हरियो रेशा उत्पादन, सुख्खा रेशा उत्पादन, हरियो लट्ठीको उत्पादन, र सुख्खा लट्ठीको उत्पादनमा उल्लेखनीय सुधार ल्यायो। विशेषगरी ३० के.जी. प्रति हेक्टरको सल्फरको मात्रामा अधिकांश सूचकहरूमा सबैभन्दा उच्च तथा प्रभावकारी नतिजा प्राप्त भयो। परीक्षण गरिएका प्रजातिहरूमध्ये, एन जे-७०१० (रानी) ले सल्फरको उपयुक्त मात्रामा लगातार उत्कृष्ट वृद्धि र उत्पादन क्षमता देखायो। अन्ततः, अध्ययनले नेपालको तराईको माटो तथा जलवायु परिस्थितिमा जुटको उत्पादकत्व र रेशा गुणस्तर सुधारका लागि ३० के.जी. प्रति

हेक्टर सल्फर सबैभन्दा उपयुक्त मात्रा रहेको निष्कर्ष निकालेको छ। सल्फरमा उत्तरदायी प्रजातिहरूलाई सन्तुलित सल्फर व्यवस्थापनसँग एकीकृत गरी अपनाउँदा घट्दो जुट क्षेत्रलाई पुनर्जीवित गर्न कम लागतमा उच्च प्रतिफल दिने व्यावहारिक रणनीति हुनसक्ने देखिन्छ।

INTRODUCTION

Jute (*Corchorus olitorius* and *C. capsularis*), renowned globally as the "golden fiber," is a cornerstone natural fiber crop in South Asia, prized for its biodegradable nature and versatile applications in textiles, packaging, and composite materials. In Nepal, cultivation is traditionally concentrated in the warm, humid, alluvial plains of the eastern Terai (Morang, Sunsari, and Jhapa districts), which offer agro-ecological suitability for its growth. Despite this potential, the national jute sector has experienced a severe and protracted decline. Recent reports indicate a drastic contraction in cultivated area from approximately 200,000 hectares in the late 20th century to a mere 7,000–8,000 hectares today, with annual production stagnating around 10,000–11,000 metric tons (MoALD 2025, CBS 2021). This trend, driven by labor-intensive harvesting and retting, price volatility, and rising production costs, has critically increased Nepal's dependence on imported raw fiber, undermining the sustainability of this indigenous, eco-friendly industry (Sharma et al 2024).

The diminishing productivity and compromised fiber quality that contribute to this decline are fundamentally linked to degraded soil fertility in the intensive jute-growing belts. Among essential nutrients, sulfur (S) has emerged as a critical limiting factor. Sulfur is the fourth major plant nutrient, vital for chlorophyll formation, protein synthesis, and the activity of key enzymes (Narayan et al 2022). For bast fiber crops like jute, sulfur plays a specific and crucial role in the biosynthesis of sulfur-containing amino acids (cystine and methionine) and in regulating lignin-cellulose metabolism, which directly governs the development of fiber strength, fineness, and length (Mondal et al 2006). However, soils in major jute-growing regions of South Asia, including Nepal's Terai, are increasingly deficient in sulfur due to intensive cultivation, the widespread use of sulfur-free or low-sulfur fertilizers (e.g., urea, DAP), and continuous nutrient removal through harvests (Ali et al 2023). This deficiency results in stunted plant growth, reduced photosynthetic efficiency, and the production of coarse and weak fiber, thereby depressing both yield and market value (Mondal et al 2006).

In the context of Nepal's contracting jute area and rising unit costs, optimizing nutrient management through strategic sulfur application represents a pragmatic and cost-effective pathway to revitalize the sector. Evidence from neighboring regions demonstrates that balanced sulfur fertilization can significantly enhance fiber yield, improve fineness and tensile strength, and increase nitrogen-use efficiency, leading to better economic returns for farmers (Mazumdar et al 2022). However, agronomic responses are highly site-specific, influenced by local soil pH, organic matter, sulfur retention capacity, and prevalent cultivars. Therefore, data generated under the distinct pedo-climatic and management conditions of the Nepalese Terai are essential to formulate credible, actionable recommendations (Timsina et al 2018). Therefore, this study was conducted for evaluate the effects of graded sulfur application on the growth, yield, and fiber quality parameters of commercially grown jute varieties in Nepal.

MATERIALS AND METHODS

Field experiments were conducted consecutively during the rainy seasons of 2022 and 2023 at the research farm of the Jute Research Program, Itahari, Nepal to find the optimum level of sulphur in different jute varieties with respect to fiber yield. The site is geographically located at approximately 26°66’46” N latitude and 87°27’18” E longitude. The site is geographically situated at 26°39′ N latitude and 87°16′ E longitude at an altitude of approximately 130 meters above sea level. The region experiences a humid subtropical monsoon climate, characterized by high temperatures (mean 28–32°C) and heavy rainfall (>2000 mm annually) during the growing season (May-September), which is ideally suited for jute cultivation. The experimental field's soil was characterized as sandy loam (Typic Haplustept) with initial soil properties determined prior to sowing. Analysis revealed a slightly acidic pH (6.2), medium organic carbon content (0.85%), and low available sulfur content (12.5 ppm), which established a baseline of sulfur deficiency conducive to this study.

The experiment was laid out in a Split-Plot Design with three replications. This design was chosen to efficiently manage the practical application of the main plot five graded levels of sulfur were applied: S0: 0 kg S/ha (Control), S10: 10 kg S/ha, S20: 20 kg S/ha, S30: 30 kg S/ha, and S40: 40 kg S/ha while precisely evaluating its interaction with sub-plot factor (four Jute Varieties): V1: Itahari 4 (JRO 524), V2: JRO

204, V3: NJ 7010 (Rani), and V4: Itahari 2. The gross plot size for each main plot (sulfur treatment) was 12 m x 3 m (36 m²). Each main plot was subdivided into four sub-plots of 3 m x 2 m (6 m²), with a 1-meter buffer between main plots and a 0.5-meter pathway between sub-plots to minimize interference.

Seeds of all varieties were treated with a recommended fungicide (Carbendazim @ 2 g/kg seed) before sowing to prevent seed-borne diseases. Sowing was completed manually in the third week of Baishakh (mid-April to early May) in lines spaced 25 cm apart. Seeds were sown at a higher density and later thinned at 10-15 Days After Sowing (DAS) to maintain a uniform intra-row spacing of 5-7 cm, achieving a final plant population of approximately 400,000 plants per hectare. A uniform basal dose of Nitrogen (N), Phosphorus (P_2O_5), and Potassium (K_2O) at 40:20:40 kg/ha was applied to all plots using Urea, Diammonium Phosphate (DAP), and Muriate of Potash (MOP), respectively. The sulfur treatments (gypsum) were applied as a basal dose during the final land preparation and thoroughly incorporated into the soil. All other intercultural operations, including weeding, irrigation, and plant protection measures against pests (semi-looper, mites) and diseases (stem rot), were carried out as per the standard package of practices recommended by JRP, Itahari, to ensure a healthy crop stand.

Harvesting was performed when plants in a plot showed flower bud formation, the physiological stage for optimal fiber yield. Data were recorded from the net harvest area of the central six rows (4.5 m²) in each sub-plot to avoid border effects. Observations recorded included**:** Phenological and Morphological Traits**:** Days to flowering, plant height at harvest (cm), and basal stem diameter (mm), Yield and Yield Attributes**:** Green plant weight (kg/plot), green stick weight (kg/plot), green fiber yield (kg/plot), dry fiber yield (kg/plot), and dry stick yield (kg/plot). Dry yields were obtained after sun-drying the fibers and sticks to a constant weight. Fiber Quality Parameter**:** Fiber fineness/thickness (Tex) was measured using a standard gravimetric method.

The data for all recorded parameters for both years were subjected to Analysis of Variance (ANOVA) appropriate for the Split-Plot Design using STAR 2.0 (Statistical Tool for Agricultural Research, version 2.0) software developed by IRRI. The significance of treatment effects (main and interaction) was tested using the F-test at a 5% probability level ($p \leq 0.05$). Where the ANOVA indicated significant differences, the treatment means were compared using Least Significant Difference (LSD) test at the 5% level of significance. A combined analysis over the two years was performed after confirming the homogeneity of error variances to draw stable and reliable conclusions.

RESULT

Effect on plant height

Analysis of variance for plant height revealed significant differences in varietal response and sulfur (S) utilization across the two growing seasons (**Table** 1). Among the tested genotypes, JRO-204 produced the tallest plants, while Itahari-2 consistently recorded the shortest stature. The varietal effect remained significant, indicating a stable genotypic expression for plant height under the prevailing edaphic and climatic conditions. The significant interaction revealed that the agronomic efficiency of sulfur was strongly genotype-dependent. At 10 kg S ha^{-1}, NJ-7010 achieved the greatest height, while Itahari-2 was severely repressed, At 20 kg S ha^{-1}, JRO-204 showed its peak response with Itahari-2 remaining the poorest performer, the most productive combination was NJ-7010 fertilized with 30 kg S ha^{-1}, achieving a maximum height and Itahari-4 recorded the lowest stature and even under the control (0 kg S ha^{-1}), NJ-7010 maintained its superior stature, with Itahari-2 again showing the minimum height. This interaction confirmed that NJ-7010 (Rani) possessed a high intrinsic responsiveness to sulfur nutrition, reaching its phenotypic potential at 30 kg S ha^{-1}. In contrast, Itahari-2 demonstrated poor adaptability and a consistently diminished stature across the sulfur gradient.

Table 1: Effect of different dose of Sulphur on jute plant height (cm) at JRP, Itahari

Treatments	**2022**					**2023**					**Combine**				
	V1	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**
10 kg Sulphur/ha	259.4	290.4	257.7	275.1	**270.6**	357.3	353.6	363.6	353.3	**356.9**	308.3	322.0	310.6	314.2	**313.8**
20 kg Sulphur/ha	282.6	296.1	277.0	272.3	**281.9**	345.9	344.4	370.9	303.2	**341.1**	314.3	320.3	323.9	287.7	**311.5**
30 kg Sulphur/ha	282.9	301.3	312.9	301.9	**299.8**	336.2	338.0	335.0	325.5	**333.7**	309.5	319.7	323.9	313.7	**316.7**
40 kg Sulphur/ha	282.6	291.8	292.5	264.7	**282.9**	357.5	387.5	391.8	381.1	**379.5**	320.1	339.6	342.1	322.9	**331.2**
Control	263.2	279.5	274.6	254.3	**272.9**	323.3	358.5	344.5	230.7	**314.3**	293.3	319.0	309.5	242.5	**293.5**
Mean	**274.1**	**291.8**	**282.9**	**273.6**	**281.6**	**344.04**	**356.4**	**361.1**	**318.7**	**345.1**	**309.1**	**324.1**	**322.0**	**296.2**	**313.3**
' - test (Variety)					**					**					**
LSD (0.05)					24.12					19.64					21.88
' - test (Treatment)					ns					**					ns
LSD (0.05)					-					21.96					
' – test (Var x Trt)					ns					*					Ns
LSD (0.05)					-					43.91					
C.V (%)					15.3					7.7					13.03

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on basal diameter

Basal stem diameter, a key trait for mechanical strength and biomass, showed contrasting patterns between years (**Table** 2). A significant varietal effect was present in 2022, with NJ-7010 (Rani) developing thicker stems than JRO-204. Sulphur treatment and its interaction with variety were non-significant. However, in 2023 and in the combined analysis, no significant effects were found for variety, sulphur, or their interaction. This demonstrated that the expression of basal stem diameter was highly sensitive to yearly environmental conditions, which overrode genotypic and treatment effects in the later season.

Table 2: Effect of different dose of Sulphur on jute basal diameter (cm) at JRP, Itahari

Treatments	**2022**					**2023**					**Combine**				
	V1	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**
10 kg Sulphur/ha	1.05	1.1	1.23	1.24	**1.15**	1.47	1.57	1.48	1.57	**1.52**	1.26	1.335	1.355	1.405	**1.335**
20 kg Sulphur/ha	1.19	1.1	1.22	1.25	**1.19**	1.6	1.43	1.46	1.23	**1.43**	1.395	1.265	1.34	1.24	**1.31**
30 kg Sulphur/ha	1.32	1.08	1.29	1.24	**1.23**	1.61	1.45	1.45	1.37	**1.47**	1.465	1.265	1.37	1.305	**1.35**
40 kg Sulphur/ha	1.3	1.3	1.23	1.17	**1.25**	1.6	1.52	1.41	1.47	**1.5**	1.45	1.41	1.32	1.32	**1.38**
Control	1.24	1.22	1.24	1.27	**1.24**	1.44	1.48	1.57	1.34	**1.46**	1.34	1.35	1.405	1.305	**1.35**
Mean	**1.22**	**1.16**	**1.24**	**1.23**	**1.21**	**1.54**	**1.49**	**1.48**	**1.39**	**1.48**	**1.382**	**1.325**	**1.358**	**1.315**	**1.344**
- test (Variety)					*					ns					Ns
LSD (0.05)					0.096					-					
- test (Treatment)					Ns					ns					ns
LSD (0.05)					-					-					
– test (Var x Trt)					Ns					ns					Ns
LSD (0.05)					-				-						
C.V (%)					14.5					12.1					11.5

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on fiber thickness

In 2022, basal stem diameter a key trait for mechanical strength and biomass showed a significant varietal effect (**Table** 2), with NJ-7010 (Rani) developing thicker stems than JRO-204. No significant effects of sulphur treatment or the variety × sulphur interaction were observed. However, in 2023 and in the combined two-year analysis, basal diameter did not differ significantly among varieties, sulphur levels, or their interaction. This indicated that year-to-year environmental variation was the primary factor modulating trait expression

Table 3: Effect of different dose of Sulphur on jute fiber thickness (cm) at JRP, Itahari

Treatments	2022					2023					Combine				
	V1	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**
10 kg Sulphur/ha	0.12	0.11	0.12	0.12	**0.12**	0.12	0.14	0.13	0.15	**0.13**	0.12	0.125	0.125	0.135	**0.13**
20 kg Sulphur/ha	0.13	0.12	0.13	0.13	**0.12**	0.14	0.13	0.12	0.11	**0.12**	0.135	0.125	0.125	0.12	**0.12**
30 kg Sulphur/ha	0.13	0.12	0.13	0.13	**0.13**	0.12	0.13	0.13	0.13	**0.13**	0.125	0.125	0.13	0.13	**0.13**
40 kg Sulphur/ha	0.13	0.13	0.12	0.12	**0.13**	0.13	0.13	0.13	0.13	**0.13**	0.13	0.13	0.125	0.125	**0.13**
Control	0.13	0.12	0.13	0.13	**0.13**	0.12	0.14	0.15	0.11	**0.13**	0.125	0.13	0.14	0.12	**0.13**
Mean	**0.13**	**0.12**	**0.13**	**0.13**	**0.12**	**0.12**	**0.13**	**0.13**	**0.12**	**0.13**	**0.127**	**0.127**	**0.129**	**0.126**	**0.125**
' - test (Variety)					Ns					ns					ns
LSD (0.05)										-					-
' - test (Treatment)					Ns					ns					ns
LSD (0.05)										-					-
' – test (Var x Trt)					*					ns					ns
LSD (0.05)					0.93										-
C.V (%)					16.9					14.7					15.8

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on green plant yield

Green plant yield was significantly influenced by the main effects of variety and sulphur dose, as well as their interaction, across both individual years and the combined analysis (**Table** 4). In 2022, variety NJ-7010 (Rani) consistently produced the highest yield across all sulphur treatments, yielding significantly more than other varieties. Among sulphur doses, application at 30 kg/ha resulted in the highest overall mean yield, which was significantly greater than the control. For instance, NJ-7010 (Rani) yielded best at 30 kg/ha, whereas Itahari-2 and Itahari-4 were superior at lower and higher doses, respectively (**Table** 4). This change contributed to a significant year × variety × sulphur interaction in the combined analysis, confirming that varietal performance was contingent upon both sulphur level and yearly environmental conditions.

Table 4: Effect of different dose of Sulphur on green plant yield ($t\ ha^{-1}$) at JRP, Itahari

Treatments	2022					2023					Combine				
	V1	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**	**V1**	**V2**	**V3**	**V4**	**Mean**
10 kg Sulphur/ha	29.4	29.1	32.3	30.5	**30.3**	34.6	35.0	36.1	35.1	**35.2**	32.0	32.1	34.2	32.8	**32.8**
20 kg Sulphur/ha	29.9	28.0	31.3	29.6	**29.7**	34.7	28.5	34.7	36.8	**33.7**	32.3	28.2	33.0	33.2	**31.7**
30 kg Sulphur/ha	31.5	35.0	32.7	32.2	**32.8**	32.2	42.2	46.5	44.6	**41.4**	31.9	38.6	39.6	38.4	**37.1**
40 kg Sulphur/ha	33.1	29.6	33.3	30.6	**31.6**	33.9	25.2	32.9	34.3	**31.6**	33.5	27.4	33.1	32.5	**31.6**
Control	23.5	28.5	26.6	22.4	**25.3**	43.6	36.0	35.2	25.9	**35.2**	33.6	32.3	30.9	24.1	**30.2**
Mean	**29.5**	**30.1**	**31.3**	**29.0**	**30.0**	**35.8**	**33.4**	**37.1**	**35.4**	**35.4**	**32.6**	**31.7**	**34.2**	**32.2**	**32.7**
F - test (Variety)					*					ns					Ns
LSD (0.05)					1.62										-
F - test (Treatment)					**					*					*
LSD (0.05)					1.81					5.07					3.44
F – test (Var x Trt)					*					*					*
LSD (0.05)					3.62					10.15					6.885
C.V (%)					7.3					17.3					12.3

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on green fiber yield

Green fiber yield was significantly influenced by variety, sulphur dose, and their interaction in both years (Table 5). Varietal yield rankings were dependent on sulphur application rate. In 2022, Itahari-4 produced the highest yields at 10 and 20 kg S ha^{-1}, whereas JRO-204 and NJ-7010 (Rani) performed better at higher doses. A consistent finding was that the application of 30 kg S ha^{-1} yielded the highest mean green fiber production across both years, a value significantly greater than that of the control. The significant variety × sulphur interaction revealed genotype-specific response patterns in 2023. NJ-7010 (Rani) achieved peak yield at the 30 kg S ha^{-1} dose while also maintaining high productivity under control conditions, indicating both strong inherent vigor and a pronounced positive response to optimal sulphur nutrition. In contrast, Itahari-4 exhibited a yield advantage at 40 kg S ha^{-1}, suggesting a distinct physiological tolerance or requirement for a higher sulphur supply. These results demonstrated that varietal selection for maximizing green fiber yield must be tailored to specific sulphur management regimes.

Table 5: Effect of different dose of Sulphur on green fiber yield (t ha^{-1}) at JRP, Itahari

Treatments	2022					2023					Combine				
	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
10 kg Sulphur/ha	14.2	10.4	9.5	10.8	**11.2**	9.6	12.1	13.6	13.4	**12.2**	11.9	11.2	11.5	12.1	**11.7**
20 kg Sulphur/ha	12.4	9.2	9.7	11.3	**10.6**	12.7	10.9	14.2	17.8	**13.9**	12.6	10.1	12.0	14.5	**12.3**
30 kg Sulphur/ha	12.5	15.1	14.1	11.7	**13.4**	16.6	18.9	20.6	19.8	**19.0**	14.55	17.00	17.35	15.75	**16.2**
40 kg Sulphur/ha	12.0	10.3	12.0	10.7	**11.2**	10.6	11.9	12	13.3	**12.0**	11.30	11.10	12.00	12.00	**11.6**
Control	8.6	10.8	9.2	9.5	**9.5**	16.7	14.4	13.1	6.3	**12.6**	12.6	12.6	11.2	7.9	**11.1**
Mean	**11.9**	**11.2**	**10.9**	**10.8**	**11.2**	**13.2**	**13.6**	**14.7**	**14.1**	**13.9**	**12.6**	**12.4**	**12.8**	**12.5**	**32.7**
' - test (Variety)					*					ns					ns
LSD (0.05)					1.62										-
' - test (Treatment)					**					*					*
LSD (0.05)					1.81					5.07					3.44
' – test (Var x Trt)					*					*					*
LSD (0.05)					3.62					10.15					6.885
C.V (%)					7.3					17.3					12.3

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on green stick yield

Green stick yield was significantly influenced by sulphur treatment and the variety × sulphur interaction, while the main effect of variety alone was non-significant (Table 6). The 30 kg S ha^{-1} treatment produced the highest overall mean yield significantly higher than the control. The significant interaction revealed that varietal performance was contingent upon the sulphur dose. The application of 30 kg S ha^{-1} consistently produced the highest mean yields for both traits. Variety NJ-7010 (Rani) demonstrated the most stable and superior performance, particularly under the optimal sulphur regime, but also maintained high productivity under low-input (control) conditions.

Table 6: Effect of different dose of Sulphur on green stick yield (t ha^{-1}) at JRP, Itahari

Treatments	2022					2023					Combine				
	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
10 kg Sulphur/ha	11.87	13.56	13.95	13.81	**13.3**	13.64	12.53	17.61	17.07	**15.21**	12.8	13.0	15.8	15.4	**14.3**
20 kg Sulphur/ha	14.63	10.74	14.64	15.23	**13.81**	17.96	12	16.61	20.14	**16.68**	16.3	11.4	15.6	17.7	**15.2**
30 kg Sulphur/ha	14.07	17.54	16.1	14.43	**15.53**	15.87	21.01	21.89	22.5	20.32	14.97	19.28	19.00	18.4	**17.93**
40 kg Sulphur/ha	16.06	13.97	16.84	14.01	**15.22**	18.3	14.26	13.8	15.56	15.48	17.18	14.12	15.32	14.7	**15.35**
Control	10.7	13.36	12.05	12.31	**12.1**	22.48	15.14	17.04	9.13	**15.95**	16.6	14.3	14.5	10.7	**14.0**
Mean	**13.47**	**13.83**	**14.72**	**13.96**	**13.99**	**17.65**	**14.99**	**17.39**	**16.88**	**16.73**	**15.6**	**14.4**	**16.1**	**15.4**	**15.36**
F - test (Variety)					ns					ns					ns
LSD (0.05)															-
F - test (Treatment)					**					**					**
LSD (0.05)					1.49					2.78					2.14
F – test (Var x Trt)					*					**					**
LSD (0.05)					2.98					5.55					4.27
C.V (%)					12.9					21.1					17.0

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on dry fiber yield

The dry fiber yield (DFY) of jute was significantly influenced by sulfur application rate and the variety × sulfur interaction across both experimental years and in the combined analysis (**Table** 7). Sulfur application substantially increased DFY compared to the control. The application of 30 kg S ha^{-1} resulted in the highest mean yield, which was 72.45 % greater than the yield of control. The significant variety × sulfur interaction indicated that varietal performance was dependent on the sulfur level. Notably, JRO-204 achieved the highest overall plot yield at 30 kg S ha^{-1}, while yielding the lowest at both 20 kg S ha^{-1} and 40 kg S ha^{-1}, demonstrating a highly specific optimal dose. The most productive variety × treatment interaction in the combined dataset was NJ-7010 under 30 kg S ha^{-1}, whereas Itahari-2 under control conditions yielded the lowest.

Table 7: Effect of different dose of Sulphur on dry fiber yield (t ha^{-1})) at JRP, Itahari

Treatments	2022					2023					Combine				
	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
10 kg Sulphur/ha	1.89	2.05	1.60	1.95	**1.87**	2.47	2.45	2.95	3.05	**2.73**	2.18	2.25	2.28	2.50	**2.30**
20 kg Sulphur/ha	1.84	1.66	1.77	2.43	**1.92**	3.70	2.32	3.93	3.42	**3.34**	2.77	1.99	2.85	2.93	**2.63**
30 kg Sulphur/ha	3.07	3.98	3.97	3.12	**3.53**	3.72	4.68	4.2	4.32	**4.23**	3.40	4.33	4.09	3.72	**3.88**
40 kg Sulphur/ha	2.36	1.86	2.58	2.22	**2.26**	2.4	2.55	2.35	3.07	**2.59**	2.38	2.21	2.47	2.65	**2.43**
Control	1.56	1.91	1.82	1.42	**1.68**	3.07	2.80	3.30	2.07	**2.81**	2.32	2.36	2.56	1.75	**2.25**
Mean	**2.14**	**2.29**	**2.35**	**2.23**	2.25	**3.07**	**2.96**	**3.35**	**3.18**	3.14	**2.61**	**2.63**	**2.85**	**2.71**	2.70
F - test (Variety)					ns					ns					ns
LSD (0.05)															-
F - test (Treatment)					**					**					**
LSD (0.05)					0.31					0.54				-	0.48
F – test (Var x Trt)					*					*					*
LSD (0.05)					.62					1.09					0.86
C.V (%)					16.9					21.0					18.9

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

Effect on dry stick yield

The effect of sulfur and variety on dry stick yield varied markedly between the two experimental years. In 2022, no significant differences were observed for variety, sulfur treatment, or their interaction. In contrast, the 2023 results revealed significant main effects of variety as well as a significant variety × sulfur interaction. Variety Itahari-4 produced the highest mean dry stick yield, while JRO-204 consistently recorded the lowest yield across all treatment levels (**Table** 8). The significant interaction was driven by this consistent ranking; Itahari-4 yielded the maximum at every sulfur application rate, with its highest yield at 30 kg S ha^{-1}. Conversely, JRO-204 consistently yielded the minimum under both treated and control conditions.

Table 8: Effect of different dose of Sulphur on dry stick yield (t ha^{-1}) at JRP, Itahari

Treatments	2022					2023					Combine				
	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
10 kg Sulphur/ha	5.08	5.32	4.31	4.6	**4.83**	8.95	5.8	7.97	8.12	**7.71**	7.02	5.56	6.14	6.36	**6.27**
20 kg Sulphur/ha	4.24	5.1	4.91	5.11	**4.84**	8.65	6.45	8.58	7.3	**7.75**	6.45	5.78	6.75	6.21	**6.30**
30 kg Sulphur/ha	5.05	5.44	4.94	4.85	**5.07**	8.62	7.40	8.27	7.93	**8.05**	6.84	6.42	6.61	6.39	**6.56**
40 kg Sulphur/ha	4.66	5	5.87	3.91	**4.86**	7.80	5.58	7.52	6.63	**6.88**	6.23	5.29	6.70	5.27	**5.87**
Control	3.41	5.7	4.22	4.71	**4.51**	10.85	7.78	4.4	8.67	**7.93**	7.13	6.74	4.31	6.69	**6.22**
Mean	**4.49**	**5.31**	**4.85**	**4.64**	**4.82**	**8.97**	**6.6**	**7.35**	**7.73**	**7.66**	**6.73**	**5.96**	**6.10**	**6.18**	**6.24**
F - test (Variety)					ns					**					**
LSD (0.05)					-					1.06					0.25
F - test (Treatment)					ns					ns					ns
LSD (0.05)					-					-					-
F – test (Var x Trt)					ns					*					ns
LSD (0.05)					-					2.38					-
C.V (%)					22.0					18.9					20.4

Note:-*, Significant at P ≤ 0.05. **, P≤0.01. LSD, least significant difference. CV, coefficient of variance, respectively. V1= Itahari 4, V2= JRO-204, V3= NJ-7010 (Rani), V4= Itahari-2

DISCUSSION

The present study demonstrated that graded sulfur application significantly influenced the growth, yield, and fiber quality of jute varieties, confirming the pivotal role of sulfur in optimizing jute productivity under Nepalese Terai conditions. Among the varieties tested, NJ-7010 (Rani) consistently exhibited superior performance in terms of plant height, green plant yield, and fiber yield, particularly at 30 kg S ha^{-1}, suggesting a strong genotypic responsiveness to sulfur nutrition. This aligns with prior observations that certain jute genotypes possess inherent vigor and efficiently utilize sulfur to achieve optimal phenotypic expression (Alam et al 2009b, Mazumdar et al 2022).

Plant height, a key determinant of biomass and potential fiber yield, was significantly influenced by both varietal differences and sulfur levels, with the highest stature recorded for NJ-7010 under 30 kg S ha^{-1}. The significant variety × sulfur interaction indicates that genotypic responses to sulfur are not uniform, reflecting the complex interplay between nutrient availability and genetic potential (Mahapatra et al 2009). Basal stem diameter, however, exhibited minimal response to sulfur in 2023 and the combined analysis, suggesting that environmental factors, such as rainfall and temperature fluctuations, might override nutrient effects on stem thickening, consistent with findings by Majumdar et al (2016).

Fiber thickness remained largely unaffected by sulfur treatment, although varietal differences were occasionally significant. This suggested that fiber fineness in jute is predominantly genotype-dependent, while sulfur plays a more pronounced role in fiber elongation and tensile strength, rather than diameter alone (Alam et al 2009b). The stability of fiber thickness across sulfur gradients indicates that moderate sulfur doses suffice to maintain fiber quality, while excessive application may not provide additional benefits (Mazumdar et al 2022).

Sulfur application notably enhanced green plant yield, green fiber yield, and dry fiber yield, with the 30 kg S ha^{-1} treatment consistently producing the highest outputs. The increase in yield parameters under optimal sulfur nutrition could be attributed to improved chlorophyll synthesis, protein formation, and enhanced enzymatic activity, which collectively promoted photosynthetic efficiency and biomass accumulation (Narayan et al, 2022). The significant variety × sulfur interactions observed for green fiber and dry fiber yields suggested that genotypic selection should be tailored to nutrient management practices for maximum productivity. For instance, NJ-7010 (Rani) attained peak green fiber yield at 30 kg S ha^{-1}, whereas Itahari-4 required 40 kg S ha^{-1} to achieve comparable yields, highlighting the necessity for site- and variety-specific sulfur recommendations. These results corroborated reports by Alam et al. (2009a), who emphasized that sulfur fertilization significantly enhances bast fiber yield and quality in sulfur-deficient soils.

Green and dry stick yields were also significantly influenced by sulfur application and varietal responses. The optimal dose of 30 kg S ha^{-1} maximized both traits, with NJ-7010 (Rani) showing stable performance across control and treated plots. This indicated that the variety not only responded positively to sulfur but also exhibited inherent resilience under low-input conditions. Conversely, Itahari-2 consistently underperformed across all sulfur levels, suggesting poor adaptability and nutrient-use efficiency. Similar genotype-specific responses to sulfur have been reported in jute cultivation in India and Bangladesh, emphasizing the importance of matching varietal traits with nutrient management strategies to enhance system productivity (Mahapatra et al 2009).

The pronounced yield improvements at moderate sulfur levels underscore the potential of targeted sulfur fertilization as a cost-effective strategy to revitalize the declining jute sector in Nepal. Given the historical reduction in jute cultivation area and declining soil fertility in the Terai, integrating balanced sulfur application into conventional nutrient management programs can improve both productivity and fiber quality, thereby increasing farmers' profitability and reducing dependence on imports (Ghimire and Thakur 2013). Moreover, varietal selection in conjunction with site-specific sulfur management could enhance resource use efficiency and ensure stable yields under variable climatic conditions, supporting sustainable jute production.

CONCLUSION

The study demonstrated that graded sulfur application significantly influenced the growth, yield, and fiber quality of jute varieties in the Terai region of Nepal. Among the varieties tested, NJ-7010 (Rani) consistently exhibited superior performance across most traits, particularly at 30 kg S ha^{-1}, indicating a strong genotypic responsiveness to sulfur nutrition. Optimal sulfur application enhanced plant height, green and dry fiber yield, and stick yield, highlighting the critical role of sulfur in chlorophyll synthesis, protein formation, and lignin–cellulose metabolism. The significant variety × sulfur interactions observed for multiple traits emphasized the necessity of variety-specific nutrient management to maximize productivity. Overall, the results suggested that 30 kg S ha^{-1} is the optimal sulfur dose for most commercially grown jute varieties under the prevailing pedo-climatic conditions of Nepalese Terai. Adoption of balanced sulfur fertilization, in conjunction with the selection of responsive varieties such as NJ-7010, could substantially improve jute yield and fiber quality, providing a cost-effective strategy to revitalize the declining jute sector in Nepal. Future studies should explore long-term sulfur management and integrate other macro- and micronutrients to sustain soil fertility and fiber quality.

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