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STUDIES ON EFFECT OF SUPER NANO UREA AND SULPHUR ON SEED YIELD AND QUALITY IN COWPEA (*VIGNA UNGUICULATA* L.)

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ABSTRACT

A field trail was performed during *Kharif* 2024 at AICRP on Arid Legumes, GKVK, UAS, Bangalore to study the effect of super nano urea and sulphur on seed yield and quality in cowpea. The study included seventeen treatments with three replications, involving RDF and different levels of recommended nitrogen and sulphur combined with foliar spray of super nano urea (2, 4 and 8 ml/l). Seed quality parameters were assessed after harvest. Application of 100 % RDF with sulphur recorded the highest plant height (51 cm), chlorophyll content (62.53), number of pods per plant (22.59), seed yield (1844 kg/ha), seed germination (92%), seed vigour index-I (3647), seed vigour index-II (5650), total dehydrogenase activity (2.65), protein content (23.76%) and benefit cost ratio (3.57), which was on par with application of 100% RDF (control) with plant height (49.72 cm), chlorophyll content (61.39), number of pods per plant (21.99), seed yield (1777 kg/ha), seed germination (91 %), seed vigour index-I (3504), seed vigour index-II (5485), total dehydrogenase activity (2.62), protein content (23.58) and benefit cost ratio (3.55) and 75% RDN & S + 2 sprays of super nano urea at 8ml/l, with plant height (47.61 cm), chlorophyll content (60.56), number of pods per plant (21.43), seed yield (1754 kg/ha), seed germination (89.67%), seed vigour index-I (3360), seed vigour index-II (5348), total dehydrogenase activity (2.52), protein content (23.45%) and benefit cost ratio (3.27). The lower performance across all parameters was recorded with 25% RDF (T_1). Application of 100% RDF with sulphur markedly enhanced seed yield and quality parameters in cowpea, closely followed by 100% RDF alone and 75% RDN & S + two sprays of super nano urea @ 8 ml/l, highlighting their effectiveness in improving productivity and seed quality over reduced nutrient levels.

Key words : Foliar spray, Super nano urea, Sulphur, Seed quality.

Introduction

Cowpea (*Vigna unguiculata* L.) is an ancient pulse crop that holds significant importance in India. It is known for its wide geographic adaptability across diverse soil types, varying levels of soil inputs and different agro-climatic regions. Valued for its high nutritional content, ability to thrive under harsh conditions and multipurpose utility. Cowpea belongs to the Fabaceae family, it is primarily cultivated for its protein-rich seeds, tender pods, and foliage, which serve as food, fodder and green manure. Due to its high protein content (ranging from 20 to 25%) and affordability, it is often referred to as the "poor man's meat." In India, cowpea is extensively cultivated in states such as Rajasthan, Karnataka, Tamil Nadu, Maharashtra and Andhra Pradesh, where it is grown both as a pulse and a vegetable crop under a wide range of agro-climatic conditions.

Cowpea is a nutritional powerhouse, boasting a rich profile of essential macronutrients and micronutrients critical for human health. Understanding the intricate biochemical composition of the seed, including its protein content and amino acid profile, carbohydrate fractions, dietary fiber, is paramount for optimizing its utilization in food systems and addressing nutritional security. It is also

packed with essential minerals such as iron, calcium, magnesium, and potassium, along with vitamins like folate, vitamin B-complex and vitamin C, which support metabolic functions and immune health. Beyond its basic nutritional components, cowpea contains bioactive compounds, including polyphenols, flavonoids, and antioxidants, which exhibit anti-inflammatory, anti-diabetic, and cardioprotective properties (USDA, 2024).

Cowpea is extensively grown across the globe, covering around 15.19 million hectares, with an annual production reaching 9.78 million metric tonnes (FAO, 2024). In India, it is grown in an area of 3.9 million ha with a production of 0.22 million metric tonnes (Government of India, 2023), where as in Karnataka, it is grown in an area of 0.94 lakh ha with a production of 0.39 lakh tonnes (Government of Karnataka, 2024).

Cowpea is well known for its excellent drought tolerance, early maturity, and adaptability to poor and marginal soils, making it an ideal crop in areas with limited rainfall and low soil fertility. Its symbiotic association with Rhizobium species enables atmospheric nitrogen fixation, reducing the need for external nitrogen fertilizers and enhancing soil health. Additionally, cowpea contributes significantly to the sustainability of cropping systems when used in crop rotation or intercropping patterns.

Despite these advantages, cowpea yields in many regions remain below their genetic potential, primarily due to suboptimal nutrient management, particularly concerning nitrogen (N) and sulphur (S). Nitrogen is one of the most critical macronutrients for plant growth and development. It is an essential constituent of amino acids, proteins, nucleic acids, chlorophyll and enzymes, all of which are vital for vegetative growth and reproductive development. However, nitrogen applied through conventional urea often shows low use efficiency due to losses through leaching, volatilization, and denitrification, leading to environmental pollution and economic loss (Kebede and Bekeko, 2020).

Nano fertilizers, serving as an alternative to traditional fertilizers, release nutrients gradually and in a controlled manner within the soil. The urgent challenges linked to the suboptimal efficiency of traditional fertilizers (30-50%) and the insufficient measures for their improvement emphasize the necessity for incorporating nano fertilizers in crop production. The rapid absorption rate of nano fertilizers not only enhances efficiency and the quality of food resources but also leads to significant reductions in soil pollution, preservation of water reserves and minimising loss of fertilizers through leaching. This approach ensures the complete absorption of fertilizers by plants and releases nutrients optimally throughout the growing season (Gowda *et al*., 2022).

In addition to nitrogen, sulphur plays a vital role in enhancing crop yield and quality. It is a component of essential amino acids like cysteine and methionine and it influences oil and protein synthesis, enzyme activity and chlorophyll formation. Sulphur also facilitates the efficient util of nitrogen within the plant, indicating a strong synergistic interaction between nitrogen and sulphur. Deficiency of sulphur, once considered rare, has become increasingly common due to the intensive use of sulphur-free fertilizers and declining atmospheric deposition (Patel *et al*., 2023).

The application of sulphur in conjunction with super nano urea holds great potential for improving cowpea productivity and seed quality. Proper sulphur nutrition can improve seed protein content, 100 seed weight, germination percentage and overall seed vigor which are critical parameters for seed quality evaluation. Therefore, balanced fertilization using innovative sources like super nano urea and appropriate levels of sulphur is essential to maximize both seed yield and quality in cowpea. The present study aims to Study the effect of super nano urea and sulphur on the seed yield and quality of cowpea (*Vigna unguiculata* L.), under field conditions. The findings of this research are expected to contribute to the development of sustainable and efficient nutrient management practices for cowpea, ensuring higher productivity, enhanced seed quality and environmental safety with the below objectives:

- Efficacy of super nano urea and sulphur on seed yield
- Effectiveness of super nano urea and sulphur on seed quality
- Cost-Benefit ratio of super nano urea and sulphur

Materials and Methods

The experiment was conducted under All India Co-ordinated Research Project on Arid Legumes, Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. The research site is situated within agro-climatic zone V: Eastern Dry Zone of Karnataka and geographically positioned at 12°58' North latitude and 77°35' East longitude with an elevation of 924 m above mean sea level. The predominant rainfall from from June to September, followed by additional precipitation from the North-East monsoon during October to December.

Sowing was done on 30th August, 2024 by using UAS Bangalore released variety KBC-9 and seed rate of 25

kg ha^{-1}. FYM was applied before 15 days of sowing to all the treatment plots at the rate of 7.5 tonnes ha^{-1}. Urea, single super phosphate and muriate of potash were used as a source of NPK and bentonite sulphur was used as a source of sulphur. Two sprays of super nano urea and sulphur at flowering and pod formation stage were given. Fertilizers were applied based on treatments. Thinning was performed at 15 days after sowing (DAS) by removing surplus seedlings from each hill, leaving only one healthy plant per hill. Earthing up at 40 DAS promoted vigorous growth and helped prevent lodging. For pest control, a foliar spray of Dimethoate at 2/ ml per liter of water was applied to control aphids and other sucking insects. At 45 DAS and 60 DAS super nano urea was sprayed based on treatments.

The crop had attained the maturity at 85 DAS. The border lines were harvested first and removed from the experimental area. Five randomly selected plants from each net plot were harvested separately for recording necessary biometric and yield observations. Subsequently, the pods from net plot area were harvested and sundried for about 4-5 days. After drying, threshing was carried out manually by beating the pods with a stick and seeds were cleaned manually. The seed seed quality analysis was carried out with completely randomized design at laboratory. The seed samples collected after harvest were evaluated for the seed germination and expressed as percentage (Anonymous, 2021). Mean seedling length and mean seedling dry weight were also measured at the end of 8 days. Seed vigour index was calculated using the formula of Abdul-Baki and Anderson (1973). The total soluble seed protein was estimated as per the method prescribed by Lowry *et al*. (1951). The dehydrogenase activity is expressed in terms of optical density at A_{480} (Perl *et al*., 1978).

Data was statistically analysed by following the analysis of variance as suggested by Snedecor and Cochran (1967). Critical difference was calculated wherever F test was found significant at 5 percent probability level and the values were furnished.

Treatment details

T_1: 25% RDN & S ($N_{25}P_{100}K_{100}S_{25}$)

T_2: 50% RDN & S ($N_{50}P_{100}K_{100}S_{50}$)

T_3: 75% RDN & S ($N_{75}P_{100}K_{100}S_{75}$)

T_4: T_1 + 2 Spray of SNU at flowering and pod formation stage @ 2ml/l

T_5 : T_1 + 2 Spray of SNU at flowering and pod formation stage @ 4ml/l

T_6 : T_1 + 2 Spray of SNU at flowering and pod formation stage @ 8ml/l

T_7: T_2 + 2 Spray of SNU at flowering and pod formation stage @ 2ml/l

T_8: T_2 + 2 Spray of SNU at flowering and pod formation stage @ 4ml/l

T_9: T_2 + 2 Spray of SNU at flowering and pod formation stage @ 8ml/l

T_{10}: T_2 + 2 Spray of SNU at flowering and pod formation stage @ 2ml/l

T_{11}: T_2 + 2 Spray of SNU at flowering and pod formation stage @ 4ml/l

T_{12}: T_2 + 2 Spray of SNU at flowering and pod formation stage @ 8ml/l

T_{13}: T_1 + 10 g/l Urea + WS @ 5g/l at flowering and pod formation stage

T_{14}: T_2 + 10 g/l Urea + WS @ 5g/l at flowering and pod formation stage

T_{15}: T_3 + 10 g/l Urea + WS @ 5g/l at flowering and pod formation stage

T_{16}: 100 % RDF (without S POP)

T_{17}: 100 % RDF ($N_{100}P_{100}K_{100}S_{100}$)

Note : RDF: 25:50:25 kg N: P_2O_5: K_2O ha^{-1}, Sulphur @ 20 kg ha^{-1}, FYM @ 7.5 t ha^{-1} common for all treatments, RDN & S: Recommended dose of nitrogen and sulphur

RDF(PK): Recommended dose of phosphorous and potassium through conventional fertilizer

SNU: Super nano urea, WS: Water soluble sulphur

Results and Discussion

Efficacy of super nano urea and sulphur on seed yield

The data in Table 1 depicts the effect of super nano urea and sulphur on plant growth parameters. Maximum plant height (51 cm), a greater number of branches (8.74), high chlorophyll content (62.53) and leaf area (995.20 cm^2 $plant^{-1}$) were recorded at 100% RDF with sulphur (T_{17}) which is closely followed by 100% RDF alone (T_{16}) [plant height (49.72 cm), number of branches (8.62), chlorophyll content (61.39) and leaf area (977.54 cm^2 $plant^{-1}$)] and treatment 75 % RDN & S + two sprays of super nano urea at 8ml/l [plant height (47.61 cm), number of branches (8.33), chlorophyll content (60.56) and leaf area (931.62 cm^2 $plant^{-1}$)]. Lowest plant height (40.53 cm), lesser number of branches (6.47), low chlorophyll content (50.24) and leaf area (694.75 cm^2 $plant^{-1}$) were recorded at 25 % RDF (T_1). The highest plant height is

Table 1 : Effect on plant growth parameters of cowpea due to super nano urea and sulphur.

Treatments	Plant height (cm)	Number of branches	Chlorophyll content (SPAD readings)	Leaf area ($cm^2 plant^{-1}$)
T_1	40.53	6.47	50.24	694.75
T_2	42.68	6.88	52.65	767.30
T_3	45.03	7.63	56.25	851.16
T_4	40.86	6.55	50.82	705.28
T_5	42.01	6.71	51.34	738.51
T_6	42.54	6.79	52.18	753.13
T_7	42.98	7.04	53.50	790.46
T_8	44.22	7.31	54.95	819.08
T_9	44.80	7.42	55.98	838.56
T_{10}	45.61	7.74	57.48	864.24
T_{11}	46.97	7.90	59.51	887.68
T_{12}	47.61	8.33	60.56	931.62
T_{13}	41.26	6.66	50.97	723.05
T_{14}	43.53	7.19	54.27	802.43
T_{15}	46.14	7.79	58.52	873.88
T_{16}	49.72	8.62	61.39	977.54
T_{17}	51.00	8.74	62.53	995.20
SEm±	**1.19**	**0.21**	**1.58**	**22.66**
CD (P=0.05)	**3.44**	**0.60**	**4.55**	**65.28**
CV (%)	**8.03**	**8.48**	**8.55**	**8.25**

attributed to the balanced supply of macro and secondary nutrients promoting cell division and elongation.

The treatments T_{12} and T_{16} are found statistically on par with T_{17} suggest that even reduced dose of chemical fertilizers supplemented with super nano urea achieve similar vegetative growth. The super nano urea leads to enhanced nitrogen use efficiency and promote rapid absorption and translocation of nitrogen. The results are in same line with studies Kumar *et al.* (2022) who observed application of RDF with sulphur significantly increased plant height due to improved metabolic activity and enzyme function and Rathore *et al.* (2023) also reported foliar application of nano urea (8 ml/l) under 75% RDN & S led to comparable growth as 100 % RDF in black gram.

The findings in Table 2 indicates the effect of super nano urea and sulphur on yield parameters. More number of pods per plant (22.59), pod length (18.41 cm), pod yield (2350 Kg/ha) and seed yield (1844 kg/ha) were recorded at 100% RDF with sulphur (T_{17}) this was nearly ranked by treatment 100% RDF alone (T_{16}) with number of pods per plant (21.99), pod length (18.05 cm), pod yield (2289 kg/ha) and seed yield (1777 kg/ha) and treatment 75 % RDN & S + 2 sprays of super nano urea at 8 ml/l recorded number of pods per plant (21.43), pod length (17.71 cm), pod yield (2244 kg/ha) and seed yield (1754 kg/ha). Lowest number of pods per plant (16.43), pod length (14.66 cm), pod yield (1704 kg/ha) and seed yield (1279 kg/ha) were recorded in 25 % RDF (T_1).

The enhanced seed yield in T_{17} can be attributed to the synergistic effect of balanced nutrient supply through RDF and the role of sulphur in protein synthesis and enzyme activation, which ultimately enhanced physiological processes responsible for better pod setting and seed filling. The comparable performance of T_{16} and T_{12} suggests that 75% RDN & S combined with super nano urea spray (T_{12}) can effectively substitute 100% RDF, making it sustainable and economical alternative.

These observations allign with those reported by Chand *et al.* (2021), who observed that the application of RDF along with sulphur significantly improved seed yield in cowpea due to better nutrient availability and uptake. Similarly, Meena *et al.* (2020) also documented that foliar application of nano urea in pulses like blackgram and cowpea significantly enhanced seed yield by improving nitrogen-use efficiency and promoting vegetative and reproductive growth.

Effectiveness of super nano urea and sulphur on seed quality

Table 3 represents the seed quality parameters of cowpea. Maximum seed germination (92.0%), a higher

Table 2 : Effect of super nano urea and sulphur on yield parameters of cowpea.

Treatments	Number of pods per plant	Pod length	Pod yield (kg/ha)	Seed yield (kg/ha)
T_1	16.43	14.66	1704	1279
T_2	18.52	15.71	1882	1434
T_3	20.14	16.88	2072	1613
T_4	16.72	14.87	1756	1328
T_5	17.84	15.43	1826	1384
T_6	18.28	15.58	1843	1412
T_7	18.77	15.87	1923	1471
T_8	19.69	16.38	2012	1545
T_9	19.82	16.62	2047	1580
T_{10}	20.54	17.03	2115	1651
T_{11}	21.13	17.52	2190	1708
T_{12}	21.43	17.71	2244	1754
T_{13}	17.32	15.01	1799	1362
T_{14}	18.92	16.09	1957	1503
T_{15}	20.85	17.33	2161	1682
T_{16}	21.99	18.05	2289	1777
T_{17}	22.59	18.41	2350	1844
SEm±	**0.56**	**0.46**	**53.74**	**47.40**
CD (P=0.05)	**1.62**	**1.33**	**154.82**	**136.55**
CV (%)	**8.69**	**8.41**	**8.02**	**9.18**

Table 3 : Effect of super nano urea and sulphur on seed quality parameters of cowpea.

Treatments	Seed germination (%)	Mean seedling length (cm)	SVI-I	SVI-II
T_1	82.00	27.37	2246	4240
T_2	85.33	30.77	2621	4631
T_3	87.33	34.24	2984	4942
T_4	82.67	27.40	2266	4345
T_5	84.33	28.84	2429	4492
T_6	85.00	29.24	2483	4571
T_7	85.67	31.83	2728	4703
T_8	86.33	33.00	2850	4803
T_9	86.67	33.30	2881	4855
T_{10}	87.67	34.90	3061	5005
T_{11}	88.33	37.30	3288	5183
T_{12}	89.67	37.50	3360	5348
T_{13}	83.33	28.67	2390	4399
T_{14}	86.00	32.57	2801	4760
T_{15}	88.00	35.63	3132	5075
T_{16}	91.00	38.54	3504	5485
T_{17}	92.00	39.67	3647	5650
SEm ±	**1.89**	**32.99**	**64.63**	**107.58**
CD (P=0.05)	**5.42**	**0.64**	**185.75**	**309.18**
CV (%)	**4.11**	**1.84**	**3.91**	**3.84**

mean seedling length (39.67 cm), greater seedling vigour index I (3647) and seedling vigour index II (5650) were recorded at 100% RDF with sulphur (T_{17}), which is comparable with 100 % RDF alone (T_{16}) seed germination (91.0 %), mean seedling length (38.54 cm), seedling vigour index I (3504) and seedling vigour index II (5485) and treatment 75% RDN & S + two sprays of super nano urea at 8ml/l seed germination (89.67%), mean seedling length (37.50 cm), seedling vigour index I (3360) and seedling vigour index II (5348). Lowest seed germination (82%), a lower mean seedling length (27.37 cm), less seedling vigour index I (2246) and seedling vigour index II (4240) were recorded in 25% RDF (T_1).

The inclusion of sulphur in T_{17} significantly contributed to better seed quality. Sulphur plays a vital role in amino acid synthesis, protein formation and enzymatic activities during seed development. These physiological improvements translate into higher seed vigour and germination potential. The treatment T_{12} (75% RDN & S + 8 ml SNU) also showed encouraging germination percentages, indicating that nano urea can partially substitute conventional nitrogen fertilizers when combined with sufficient base nutrients. However, as RDF was reduced, the effect was slightly less pronounced than in full RDF treatments. These findings were consistent with reports of Prasad *et al*. (2019) and Kumar *et al*. (2021).

Table 4 : Effect of super nano urea and sulphur on seed biochemical parameters of cowpea.

Treatments	Seed protein content (%)	Total dehydrogenase activity (A_{480} nm)	Peroxidase activity (A_{436} nm)
T_1	21.19	1.64	0.205
T_2	21.90	1.93	0.224
T_3	22.76	2.27	0.241
T_4	21.28	1.70	0.208
T_5	21.36	1.81	0.214
T_6	21.50	1.85	0.218
T_7	22.03	2.00	0.229
T_8	22.19	2.15	0.231
T_9	22.41	2.20	0.235
T_{10}	22.90	2.34	0.249
T_{11}	23.01	2.49	0.270
T_{12}	23.45	2.56	0.280
T_{13}	21.72	1.78	0.210
T_{14}	22.58	2.08	0.236
T_{15}	23.37	2.41	0.261
T_{16}	23.58	2.62	0.300
T_{17}	23.76	2.65	0.314
SEm ±	**0.56**	**0.05**	**0.006**
CD (P=0.05)	**1.62**	**0.14**	**0.018**
CV (%)	**4.36**	**3.87**	**4.570**

Data in table 4 pertains biochemical properties of cowpea seeds. Highest seed protein content (23.76 %), total dehydrogenase activity (2.65) and peroxidase activity (0.314) were recorded at 100% RDF with sulphur (T_{17}) which is statistically on par with 100% RDF alone (T_{16}) with seed protein content (23.58 %), total dehydrogenase activity (2.62) and peroxidase activity (0.30) and treatment 75% RDN & S + two sprays of super nano urea at 8 ml/l (T_{12}) with seed protein content (23.45 %), total dehydrogenase activity (2.56) and peroxidase activity (0.28). Lower seed protein content (21.19 %), total dehydrogenase activity (1.64) and peroxidase activity (0.205) recorded in 25% RDF (T_1).

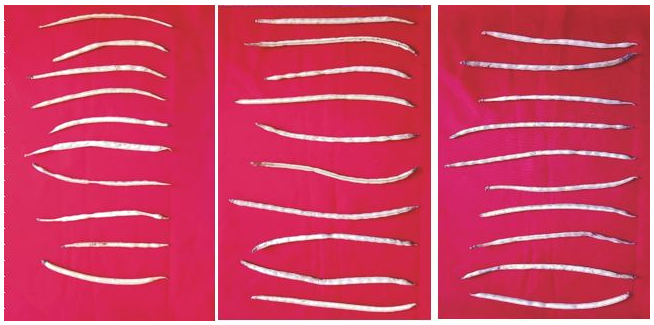
The superior performance of T_{17} can be attributed to the combined application of RDF and sulphur, which plays a vital role in enzyme activation and oxidative stress management. Sulphur-containing amino acids such as cysteine and methionine which are fundamental building blocks of proteins serve as precursors for antioxidant enzymes, including peroxidases, enhancing seed metabolic stability and resistance to deterioration.

Cost-Benefit ratio of super nano urea and sulphur

Table 5 reflects the economics of cowpea influenced by super nano urea and sulphur. Higher B:C ratio is observed in T_{17}, 100% RDF with sulphur (3.57), which is nearly followed by 100% RDF alone (3.55) and 75% RDN & S + 2 sprays of super nano urea

Table 5 : Effect of super nano urea and sulphur on economics of cowpea seed cultivation.

Treatments	Cost of Cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1	50170	127924	77754	2.55
T_2	50655	143416	92760	2.83
T_3	51141	161279	110138	3.15
T_4	50795	132873	82078	2.62
T_5	51420	138449	87029	2.69
T_6	52670	141239	88570	2.68
T_7	51280	147078	95798	2.87
T_8	51905	154530	102625	2.98
T_9	53155	158029	104873	2.97
T_{10}	51766	165127	113362	3.19
T_{11}	52391	170809	118418	3.26
T_{12}	53641	175366	121725	3.27
T_{13}	51839	136239	84400	2.63
T_{14}	52325	150341	98016	2.87
T_{15}	52810	168244	115434	3.19
T_{16}	50071	177716	127645	3.55
T_{17}	51626	184428	132801	3.57



25% RDF (T_1) | 75% RDN & S + SNU @ 8ml/l (T_{12}) | 100% RDF + sulphur (T_{17})

Fig. 1 : Influence of super nano urea and sulphur on pod length.

25% RDF (T_1) | 75% RDN & S + SNU @ 8ml/l (T_{12}) | 100% RDF+ sulphur (T_{17})

Fig. 2 : Influence of super nano urea and sulphur on mean seedling length.

at 8ml/l (3.27) and lower B:C ratio is noted in 25% RDF (2.55). The higher gross returns, net returns and B: C ratio were the result of higher seed yield, that is obtained due to the combined application of 100 % RDF and sulphur followed by 100% RDF and 75% RDN & S + 2 sprays of SNU @ 8ml/l which might have facilitated the greater availability of essential nutrients to plant and better translocation of photosynthates, ultimately resulted in higher seed yield.

Conclusion

The study clearly signifies the basal application of RDF along with sulphur @ 20 kg/ha plays a pivotal role in cowpea growth and productivity. Among the treatments, 75% RDN & S combined with foliar spray of Super Nano Urea @ 8 ml/l (T_{12}) recorded results comparable to 100% RDF + sulphur (T_{17}), indicating that a reduced basal dose when strategically supplemented with super nano urea, can sustain optimal crop performance. This underscores the importance of a sufficient basal nutrient supply as a foundation, while super nano urea enhances nutrient use efficiency and complements crop needs during critical growth stages. Therefore, 75% RDN & S + SNU emerges as a promising strategy to reduce fertilizer input without compromising seed yield and quality. The inclusion of sulphur in the nutrient regime notably enhanced seed quality traits such as germination, seedling vigour and biochemical properties. Sulphur plays a crucial role in enhancing the biochemical properties of seeds by supporting protein synthesis, enzyme activity and maintaining membrane integrity, thereby improving seed quality and vigour. Thus, a combination of balanced basal fertilization and targeted sulphur supplementation ensures sustainable productivity and seed quality in cowpea.

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