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Effect of sulphur and boron on growth, yield and nutrient uptake of chickpea (*Cicer arietinum* L.)

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Abstract
A field experiment entitled "Effect of sulphur and boron on growth, yield and nutrient uptake of chickpea (*Cicer arietinum* L.)" was conducted at ICAR-Krishi vigyan Kendra, Kalaburagi during *Rabi* 2023. The experiment was laid out in Randomized Complete Block Design with ten treatments and three replications. The experimental results revealed that the treatment receiving RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (T_{10}) as soil application recorded significantly higher yield parameters viz. grain yield (1712 kg ha^{-1}), stover yield (3564 kg ha^{-1}) and harvest index (32.47%) when compared to RPP only (T_2). Further, growth parameters *viz*., plant height at harvest (42.10 cm), number of branches $plant^{-1}$ (5.7), total dry matter (20.1 g $plant^{-1}$), number of pods $plant^{-1}$ (33.21), 100 test weight (21.40 g), gross returns and net returns (Rs 94212 ha^{-1} and Rs 58184 ha^{-1} respectively) were also recorded significantly higher with soil application of RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (T_{10}). However, it was found at par with the treatments T_9-RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax, T_8-RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax and T_7-RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax. However, significantly lowest was recorded in (T_1) absolute control.

Keywords: Chickpea, sulphur, boron, growth, yield, nutrient uptake

Introduction
Chickpea (*Cicer arietinum* L.) is the most important ancient pulse crop being traditionally grown during *Rabi* season in India and cultivated mainly in semi-arid and warm temperate regions of world where the temperature is 20-30 °C (Reddy, 2009). Chickpea has a considerable amount of protein (23%), carbohydrate (63%), fat (5%), crude fiber (6%), ash (3%), dietary fiber, unsaturated fatty acids such as linoleic and oleic acid and minerals such as calcium, magnesium, phosphorous and especially potassium. The protein quality of chickpea is believed to be superior to that of other pulses. It can be utilized to make nutritionally value-added foods, which can then be used to feed low income people in developing countries. (Mula *et al.*, 2011) [12].

The sulphur helps in the formation of plant proteins, and it is essential for the formation of chlorophyll and improves root growth. Sulphur is involved in the formation of vitamins and enzymes required for the plant to conduct its biochemical processes. A deficiency of sulphur affects a plant's protein synthesis, structure, and chlorophyll production and overall plant development and growth are stunted. Sulphur deficiency in Indian soil adversely affects crop production besides recommended dose of NPK fertilizers application (Surendra and Singh, 2008) [24]. Boron is an important micronutrient critical to the growth and health of all crops. It is a component of plant cell walls and reproductive structures. It is a mobile nutrient within the soil, meaning it is prone to movement within the soil. Because it is required in small amounts, it is important to deliver B as evenly as possible across the field. Boron plays an important role in new cell development in meristemetic tissues, proper pollination and fruit or seed formation and nodule formation in legumes. It is also involved in cell wall formation, cell division and maintenance of structural and functional integrity of biological membranes, translocation of sugars, synthesis of amino acid, protein, carbohydrate metabolism and movement of N, P, starch and sugar (Marschner, 1986) [15]. Deficiency of boron causes inhibition of cell expansion, death of meristem, and reduced fertility. Despite the need for this critical nutrient, B is the second most widespread micronutrient deficiency problem worldwide after zinc.

The impact of nitrogen and sulphur application on quality parameter and yield was highly significant in mustard (Sharma *et al*., 2023) [18]. Soil application of sulphur (20 kg ha^{-1}) through bentonite sulphur @ 22 kg ha^{-1}, foliar application of zinc (0.5%) through zinc sulphate @ 2.5 kg ha^{-1} and foliar spray of boron (0.1%) through solubor @ 0.5 kg ha^{-1} along with recommended dose of fertilizers became determined superior not only in increasing the fruit yield however additionally improved quality and economics of watermelon crop (Adarsh *et al.*, 2024) [1].

Material and Methods

A field experiment entitled "Effect of sulphur and boron on growth, yield and nutrient uptake of chickpea (*Cicer arietinum* L.)" was carried out during *Rabi* season, 2023-24 at institutional farm of ICAR-Krishi Vigyan Kendra, Kalaburagi which belongs to North Eastern Dry Zone (Zone-2) of Karnataka state. The details of material used and experimentation methods followed during the course of investigation are presented in this chapter.

The field Experiment was conducted in a RCBD (Randomized complete block design) design with ten treatments and three replications. Spacing followed is 30 cm x 10 cm. The treatment details as follows ; T_1-Absolute control, T_2-RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1}),T_3-RPP + 20 kg ha^{-1} Sulphur, T_4-RPP + 30 kg ha^{-1} Sulphur, T_5-RPP + 2.5 kg ha^{-1} Borax, T_6-RPP + 5 kg ha^{-1} Borax, T_7-RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax, T_8-RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax, T_9-RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax, T_{10}-RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax, T_{11}-Absolute control. Recommended dose of FYM was applied to all the treatment, except control. The fertilizer recommendation for chickpea was followed as per recommended package of practice (POP) of University of Agricultural Sciences, Raichur (10:25:00 Kg N: P_2O_5: K_2O per hectare). Variety used is Super Annigeri. Rainfall received during the crop growth period was 332 mm from October 2023 to January 2024. The maximum and minimum air temperature during crop growth period (May 2023 and January 2023-24) is 38.01 °C and 16.71 °C, respectively. Observations on growth and yield parameters were recorded as per standard procedures. The nutrient availability (N, P and K as per the standard procedure given by Jackson, 1973) [9] and uptake were recorded at harvest stage of crop. The cost of cultivation was computed taking into consideration the cost of various operations and inputs used for raising the crop. The gross returns computed using the prevailing market price for the produce. The net returns were computed by deducting the cost of cultivation from the gross returns. The benefit cost ratio was worked out by dividing the gross returns by cost of cultivation. The experimental data recorded were analysed statistically as per Analysis of Variance (ANOVA) technique suggested by Gomez and Gomez (1984) [6].

Results and Discussion

Effect of different levels of Sulphur and Boron on growth parameters of chickpea

The data on growth parameters *viz*., plant height (cm), number of branches $plant^{-1}$ at different stages of crop growth (30, 60 DAS and at harvest) and total biomass (kg ha^{-1}) at harvest as influenced by different levels of sulphur and boron on chickpea are presented in Tables 1 to 3.

Plant height (cm)

The plant height of chickpea differs significantly at various stages of crop growth stages due to the application of sulphur and boron at different levels.

At 30 DAS, the plant height of chickpea did not differed significantly due to application of different levels of sulphur and boron on chickpea crop (Table 1). However, highest plant height (17.43 cm) was noticed in T_{10} treatment (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) and lowest plant height (13.29 cm) was recorded in the absolute control.

At 60 DAS, the plant height of chickpea varied significantly among the treatments. The Treatment T_{10} (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) recorded significantly highest plant height of 31.88 cm and it was on par with T_9 : RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (31.47 cm), T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (30.52) and T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (29.94 m). However, significantly lowest plant height (22.37 cm) was recorded in (T_1) absolute control.

Significantly higher plant height (42.10 cm) at harvest was recorded in the T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax. But, it was on par with T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (41.85 cm), T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (41.67 cm) and T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (40.53 cm). Whereas, significantly lowest plant height (25.70 cm) was recorded in (T_1) absolute control.

Table 1: Effect of different levels of sulphur and born on plant height at different growth stages of chickpea

Treatments	Plant height (cm)		
	30 DAS	60 DAS	At harvest
T_1: Absolute control	13.29	22.37	25.70
T_2: RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1})	13.43	24.33	27.93
T_3: RPP + 20 kg ha^{-1} Sulphur	15.25	28.24	38.11
T_4: RPP + 30 kg ha^{-1} Sulphur	15.56	28.81	39.18
T_5: RPP + 2.5 kg ha^{-1} Borax	14.77	26.96	36.51
T_6: RPP + 5 kg ha^{-1} Borax	14.98	27.67	37.54
T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	16.47	29.94	40.53
T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	16.41	30.52	41.67
T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	16.95	31.47	41.85
T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	17.43	31.88	42.10
S. Em.±	1.02	0.82	1.01
C.D. at 5%	NS	2.37	2.91

Number of branches plant^{-1}

The data on the number of branches plant^{-1} of chickpea at different stages (30, 60 DAS and harvest) as influenced by different levels of sulphur and boron are presented in Table 2.

At 30 DAS, the number of branches plant^{-1} was not differed significantly due to application of different levels of sulphur and boron. However, higher number of branches (3.4) was noticed in the $T_{10:}$ RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax and lower number of branches (2.1) was observed in the treatment (T_1) absolute control.

The crop growth reached on advanced vegetative stage at 60 DAS. Significantly higher number of branches plant^{-1} (4.9) were recorded in the (T_{10}) RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax. However, it was found on par with (T_9) RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (4.7), (T_8) RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (4.4) and treatment (T_7) RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (4.3). Significantly lower branches plant^{-1} (2.2) were recorded in T_1 as a absolute control.

At harvest, same trend was followed T_{10} treatment with application of RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax was recorded significantly highest number of branches plant^{-1} (5.7) and it was on par with $T_{9,}$ where RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (5.4) followed by treatments T_8 where RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (5.0 cm) and T_7 which received RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (4.9 cm). Whereas, significantly lower number of branches per plant (2.4 cm) was recorded in (T_1) absolute control.

An increase in the number of branches per plant observed in the T_{10} treatment (recommended package of practice + 30 kg ha^{-1} sulphur + 5 kg ha^{-1} borax) can be attributed to the highest growth parameters such as plant height, number of branches and dry matter production in chickpea. This outcome can be attributed to several key factors supported by scientific research. This increase growth parameters can be attributed to the significant physiological and biochemical effects of supplied nutrients. Application of sulphur a key role in formation of chlorophyll resulting in higher photosynthesis which leads to increase growth parameters. And also Sulphur enhances the synthesis of key amino acids and proteins essential for developing new plant tissues, including growth hormones like auxins, which are crucial for branching and shoot development. It also aids in the production of secondary metabolites that further support lateral branch formation. Application of boron might be due to the role of boron in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink. Similar results were reported by Ram and Katiyar (2013) [16], Kumawat *et al.* (2014) [11], and Singh *et al.* (2015) [19]. They reported that increase in plant height, number of branches and dry matter production are due to boron fertilization. And also boron optimizes nutrient uptake and utilization, strengthens cell walls, and facilitates the movement of nutrients and sugars within the plant. This ensures that more resources are allocated to structural tissue production, leading to increased dry matter. Similar findings have been reported by Jha *et al.* (2015) [10] and Singh *et al.* (2016) [20], underscoring the effectiveness of sulphur and boron applications in improving crop productivity.

The combined application of sulphur and boron, alongside conventional fertilizers, improves the plant's overall health and stress tolerance, allowing it to allocate more resources to branch development. This synergistic effect of sulphur and boron, confirmed by research from Ram and Katiyar (2013) [16], Jadeja *et al.* (2016) [8], and Singh *et al.* (2016) [20], leads to a notable increase in the number of branches per plant, demonstrating the effectiveness of these nutrients in enhancing chickpea growth.

Table 2: Effect of different levels of sulphur and boron on number of branches plant^{-1} at different growth stages of chickpea

Treatments	Number of branches per plant		
	30 DAS	60 DAS	At harvest
T_1: Absolute control	2.1	2.2	2.4
T_2: RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1})	2.2	2.8	3.2
T_3: RPP + 20 kg ha^{-1} Sulphur	2.6	3.5	4.0
T_4: RPP + 30 kg ha^{-1} Sulphur	2.9	3.9	4.3
T_5: RPP + 2.5 kg ha^{-1} Borax	2.4	3.0	3.6
T_6: RPP + 5 kg ha^{-1} Borax	2.6	3.4	3.9
T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	3.0	4.3	4.9
T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	3.1	4.4	5.0
T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	3.3	4.7	5.4
T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	3.4	4.9	5.7
S. Em.±	0.33	0.23	0.31
C.D. at 5%	NS	0.76	0.83

Dry matter production and its accumulation (g plant^{-1})

The data on the total dry matter production of chickpea at different stages (30, 60 DAS and harvest) as influenced by different levels of sulphur and boron are presented in Table 3.

At 30 DAS, the total dry matter production was not differed significantly due to application of different levels of sulphur and boron. However, higher total dry matter production (0.93 g plant^{-1}) was noticed in the T_{10} treatment (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) and lowest total dry matter production (0.75 g plant^{-1}) was observed in the treatment (T_1) as absolute control.

At 60 DAS, Significantly higher total dry matter production (12.2 g plant^{-1}) was recorded in the treatment T_{10} with an application of RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax, which was on par with (T_9) RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (11.8), (T_8) RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (11.2 g plant^{-1}) and (T_7) RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (10.9 g plant^{-1}). However, lower drymatter production plant^{-1} (7.7 g plant^{-1}) was recorded in T_1 as absolute control.

At harvest, T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax was recorded significantly higher total dry matter accumulation (20.1 g plant^{-1}) and it was on par with T_9: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (19.3 g plant^{-1}), T_8:

RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (18.3 g plant^{-1}) and T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (17.9 g plant^{-1}). While, significantly lowest total dry matter accumulation (14.1 g plant^{-1}) was recorded in (T_1) absolute control.

Table 3: Effect of different levels of sulphur and boron on dry matter production plant^{-1} at different growth stages of chickpea

Treatments	Total dry matter production(g plant^{-1})		
	30 DAS	60 DAS	At harvest
T_1: Absolute control	0.75	7.7	14.1
T_2: RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1})	0.79	8.4	14.8
T_3: RPP + 20 kg ha^{-1} Sulphur	0.82	10.3	17.3
T_4: RPP + 30 kg ha^{-1} Sulphur	0.83	10.4	17.7
T_5: RPP + 2.5 kg ha^{-1} Borax	0.80	8.9	15.1
T_6: RPP + 5 kg ha^{-1} Borax	0.81	9.5	15.5
T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	0.85	10.9	17.9
T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	0.87	11.2	18.3
T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	0.91	11.8	19.3
T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	0.93	12.2	20.1
S. Em.±	0.12	0.80	1.10
C.D. at 5%	NS	2.20	3.30

Effect of different levels of Sulphur and Boron on yield parameters of chickpea.

The data on yield parameters such as number of pods per plant, test weight, grain yield, stover yield and harvest index of chickpea at harvest as influenced by different levels of sulphur and boron are presented in Tables 4 to 5.

Number of pods plant^{-1}

The data on the number of pods plant^{-1} of chickpea at harvest as influenced by different levels of sulphur and boron are presented in Table 4.

At harvest, number of pods plant^{-1} was significantly higher in (T_{10}) RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (33.21 plant^{-1}) when compared to rest of the treatment combinations. However it was on par with the (T_9) RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (31.69 plant^{-1}), (T_8) RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (31.14 plant^{-1}) and (T_7) RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (30.52 plant^{-1}). Significantly lowest number of pods plant^{-1} (20.61 plant^{-1}) was observed in absolute control.

The treatment T_{10} (recommended package of practice + 30 kg ha^{-1} sulphur + 5 kg ha^{-1} borax) achieved the highest number of pods per plant due to the combined benefits of these nutrients on plant health and productivity. Sulphur enhances plant metabolism by promoting the synthesis of amino acids and proteins essential for flower and pod formation. Addition of boron helps to regulate growth hormones for pod formation and development. This increase in pod numbers is due to the adequate supply of essential nutrients throughout the growth stages of chickpea, promoting better growth and development. Similar results have been reported by Goyal *et al.* (2010) [7], Ram and Katiyar (2013) [16], Das *et al.* (2017) [2], and Duhan *et al.* (2018) [4].

Test weight (100 seeds)

The data in the Table 4 indicated that there was no significance difference in test weight at harvest of chickpea among all the treatments. However, the test weight value ranges from 18.10 g to 21.40 g. Highest test weight (21.40 g) was recorded in T_{10} (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) and lowest was observed in absolute control (18.08 g).

Grain yield (kg/ha)

Significant difference in the grain yield of chickpea (kg ha^{-1}) was observed due to different levels of sulphur and boron. The results are shown in the Table 5.

Significantly higher grain yield (1712 kg ha^{-1}) at harvest was recorded in the T_{10} (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) when compared to all other treatments. But, it was par with (T_9) RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (1697 kg ha^{-1}), (T_8) RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (1634 kg ha^{-1}) and (T_7) RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (1614 kg ha^{-1}). However, significantly lowest grain yield (973 kg ha^{-1}) was recorded in T_1 absolute control.

The highest seed yield was obtained by application of (T_{10}) recommended package of practices along with 30 kg ha^{-1} of sulphur and 5 kg ha^{-1} of borax, which might be due to the cumulative favourable effect of more number of branches, higher pod yield and seed yield per plant in chickpea. Application of Boron @ 5 kg ha^{-1} through borax was found to be significant over without application of boron on seed, it might be due to increase in plant height and number of branches per plant as a result of cell wall strength, cell division and sugar transport which are plant functions related to boron. The similar trend was also observed on harvest index. Similar findings were reported by Sharma and Abraham (2010) [22]. Sulphur improves soil fertility by increasing the availability of essential nutrients such as phosphorus and potassium. It lowers soil pH, which enhances nutrient solubility and accessibility, leading to better nutrient uptake and higher crop yields. The combined application of sulphur and boron with the recommended practices ensures a well-balanced nutrient supply, optimizing both vegetative and reproductive growth. Similar results were reported by Goyal *et al.* (2010) [7].

Stover yield (kg/ha)

There was a significant difference in the stover yield of chickpea (kg ha^{-1}) due to the application of different levels of sulphur and boron. The results are shown in the Table 5.

Significantly higher stover yield (3564 kg ha^{-1}) was recorded in the T_{10} treatment (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) but, it was on par with (T_9) RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (3482 kg ha^{-1}) followed by (T_8)

RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax (3475 kg ha^{-1}) and (T_7) RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax (3386 kg ha^{-1}). While, significantly lowest stover yield (2132 kg ha^{-1}) was recorded in absolute control ($T_{1)}$.

The significantly highest stover yield was observed in the treatment $T_{10,}$ which combines the recommended package of practices with 30 kg ha^{-1} of sulphur and 5 kg ha^{-1} of borax, can be explained by several key factors. The difference in the stover yield was largely because of variations in yield components such as number of pods plant^{-1}, seed yield plant^{-1} and test weight. It might be due to higher yield components that are directly responsible for seed yield appeared to be determined by physiological characters both during vegetative and reproductive phases of the crop growth. Sulphur enhances soil fertility by increasing the availability of essential nutrients such as phosphorus and potassium. It lowers soil pH, which improves solubility of nutrients and accessibility, leads to better nutrient uptake. This results in more robust stem and leaf development, directly contributing to a higher stover yield. Boron plays a critical role in plant health and supports cell wall formation, root development, and nutrient transport. Its application strengthens plant structures and boosts biomass production, including stover. The integration of sulphur and boron with the recommended practices ensures a balanced nutrient supply and optimal growth conditions, leading to increased stover yield. Research by Farhad *et al.* (2010) [5], Deshbharatar *et al.* (2010) [3], Ram and Katiyar (2013) [16], and Mahilane and Singh (2018) [14] in their findings, showing that sulphur and boron applications significantly enhance biomass production. Thus, the T_{10} treatment T_{10} has effectively boosts both stover and grain yields by promoting vigorous vegetative growth and overall plant health.

Harvest index

Harvest index did not vary significantly due to application of different levels of sulphur and boron**.** However, higher harvest index (32.47%) was recorded in the T_{10} (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) and lowest harvest index (31.35%) was observed in T_1: (absolute control).

Table 4: Effect of different levels of sulphur and boron on number of pods plant^{-1} and 100 seed weight of chickpea

Treatments	No. of pods plant^{-1}	100 seed weight (g)
T_1: Absolute control	20.61	18.08
T_2: RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1})	23.74	18.36
T_3: RPP + 20 kg ha^{-1} Sulphur	27.47	19.67
T_4: RPP + 30 kg ha^{-1} Sulphur	28.47	19.88
T_5: RPP + 2.5 kg ha^{-1} Borax	26.20	18.73
T_6: RPP + 5 kg ha^{-1} Borax	26.96	19.05
T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	30.52	20.01
T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	31.14	20.33
T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	31.69	20.68
T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	33.21	21.40
S. Em.±	0.93	0.76
C.D. at 5%	2.73	NS

Table 5: Effect of different levels of sulphur and boron on seed yield, stover yield and harvest index of chickpea

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1: Absolute control	973	2132	31.35
T_2: RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1})	1244	2689	31.66
T_3: RPP + 20 kg ha^{-1} Sulphur	1569	3229	32.68
T_4: RPP + 30 kg ha^{-1} Sulphur	1604	3302	32.70
T_5: RPP + 2.5 kg ha^{-1} Borax	1539	2966	34.15
T_6: RPP + 5 kg ha^{-1} Borax	1558	3172	32.94
T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	1614	3386	32.29
T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	1634	3475	32.00
T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	1697	3482	32.78
T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	1712	3564	32.47
S. Em.±	35.00	67.02	0.62
C.D. at 5%	102.02	197.08	NS

Effect of different levels of sulphur and boron on economics of chickpea cultivation

Cost of cultivation (₹ ha^{-1})

The data pertaining to the cost of cultivation incurred in chickpea production as influenced by various treatments is presented in Table 6.

Higher cost of cultivation per hectare (36028 ha^{-1}) was recorded in T_{10} treatment with the application of RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax and it was on par with T_9, T_8 and T_7 whereas lowest cost of cultivation (₹29804 ha^{-1}) was recorded in T_1: (absolute control) as compared to other treatments.

Gross Returns (₹ ha^{-1})

The data pertaining to the gross returns as influenced by various treatments is presented in Table 6 and depicted in fig. 10.

Significantly higher gross returns per hectare were recorded in T_{10} treatment (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) (₹94212ha^{-1}) and lower gross returns was in T_1 (₹53593ha^{-1}).

Net Returns (₹ ha^{-1})

The data pertaining to the net returns as influenced by various treatments is presented in Table 6 and depicted in fig. 10

Higher net return per hectare was recorded with the application of T_{10} treatment (RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax) (₹ 58184 ha^{-1}) and lower net returns was in T_1 (₹ 23789 ha^{-1}).

Benefit Cost Ratio

Higher benefit cost ratio was recorded with the application T_9 treatment (RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax) (2.63) and it was on par with treatment T_{10}, T_8 and T_7. However, lower benefit cost ratio was with T_1: Absolute control (2.08).

The significant increase in gross returns, net returns, and benefit-cost ratio observed in the T_{10} treatment, which includes the recommended package of practices along with 30 kg ha^{-1} of sulphur and 5 kg ha^{-1} of borax, can be attributed to several factors. Sulphur enhances soil fertility by increasing the availability of essential nutrients such as phosphorus and potassium through soil pH adjustment and promoting organic matter decomposition. This leads to better nutrient uptake by plants and higher crop yields. Boron supports critical plant functions like root development and nutrient transport, further improving crop productivity.

Research by Singh *et al.* (2005) [21] confirms that sulphur and boron significantly enhance nutrient dynamics and crop yields. The combined application of these nutrients ensures a balanced nutrient supply, optimizing plant growth and yield. Higher yields and improved produce quality result in increased market value, leading to greater gross and net returns. The improved benefit-cost ratio reflects that the extra investment in sulphur and boron is more than offset by the increased returns from higher yields and better crop quality. These results are consistent with findings from Subramaniyan *et al.* (2001) [23] and Mukund Gowda *et al.* (2015) [17], which highlight the economic benefits of effective nutrient management.

Table 6: Effect of different levels of sulphur and boron on economics of chickpea cultivation

Treatments	Cost of Cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1: Absolute control	29804	53593	23789	2.08
T_2: RPP (10:25:00; N:P_2O_5:K_2O: kg ha^{-1})	32928	68503	35575	2.52
T_3: RPP + 20 kg ha^{-1} Sulphur	34328	86337	52009	2.52
T_4: RPP + 30 kg ha^{-1} Sulphur	35028	88247	53219	2.53
T_5: RPP + 2.5 kg ha^{-1} Borax	33428	84581	51153	2.53
T_6: RPP + 5 kg ha^{-1} Borax	33928	85695	51767	2.55
T_7: RPP + 20 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	34828	88849	54021	2.55
T_8: RPP + 20 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	35328	89959	54631	2.61
T_9: RPP + 30 kg ha^{-1} Sulphur + 2.5 kg ha^{-1} Borax	35528	93383	57855	2.63
T_{10}: RPP + 30 kg ha^{-1} Sulphur + 5 kg ha^{-1} Borax	36028	94212	58184	2.61
S. Em.±		1875	1875	0.16
C.D. at 5%		5498	5498	2.08

Conclusion

On the basis of results obtained during the course of present experimentation, following conclusions can be drawn. Application of recommended dose of fertilizer (10:25:00 NPK kg ha^{-1}) to chickpea crop along with soil application of sulphur @ 30 kg ha^{-1} through bentonite and boron @ 5 kg ha^{-1} in the form of borax was found beneficial for increasing growth parameters, yield and economics of chickpea crop.

References

1. Adarsh JK, Basavaraj, Rajesh NL, Chethan T, Mahanthesh MT. Effect of sulphur, zinc and boron on growth, yield and economics of watermelon (*Citrullus lanatus* (Thunb.)) in vertisol of Northern Karnataka. Biological Forum-An International Journal. 2024;16(2):117-120.
2. Das SK. Effect of phosphorus and sulphur on yield attributes, yield, nodulation and nutrient uptake of greengram (*Vigna radiata* L.). Legume Research. 2017;40(1):138-143.
3. Deshbhratar PB, Singh PK, Jambhulkar AP, Ramteke DS. Effect of sulphur and phosphorus on yield, quality and nutrient status of pigeonpea (*Cajanus cajan* L.). Journal of Environmental Biology. 2010;31(6):933-937.
4. Duhan DS, Rana MK, Singh H, Mazoka M. Effect of phosphorus and zinc on plant growth and yield of vegetable cowpea. Vegetable Science. 2018;45(1):55-60.
5. Farhad ISM, Islam MN, Hoque S, Bhuiyan MSI. Role of potassium and sulphur on the growth, yield and oil content of soybean. Journal of Plant Sciences. 2010;3(2):99-103.
6. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. New York: John Wiley and Sons; 1984. p. 1-680.
7. Goyal S, Verma HD, Nawange DD. Studies on growth and yield of Kabuli chickpea genotypes under different plant densities and fertility levels. Legume Research. 2010;33(3):221-223.
8. Jadeja AS, Rajani AV, Foram, Chapdiya, Kaneriya SC, Kavar NR. Soil application of potassium and sulphur and effect on growth and yield components of chickpea (*Cicer arietinum* L.) under south Saurashtra region of Gujarat. International Journal of Science, Environment and Technology. 2016;5(5):3172-3176.
9. Jackson ML. Soil Chemical Analysis. New Delhi: Prentice Hall of India Pvt. Ltd.; 1973. p. 1-498.
10. Jha DP, Sharma SK, Amarawat T. Effect of organic and inorganic sources of nutrients on yield and economics of blackgram (*Vigna mungo* L.) grown during Kharif. Agricultural Science Digest. 2015;35(3):224-228.
11. Kumawat SR, Khistriya MK, Yadav SL, Kumar M. Effect of sulphur and phosphorus on growth and yield attributes of summer greengram (*Vigna radiata* (L.) Wilczek). International Journal of Agricultural Sciences. 2014;10(2):770-773.

12. Mula MG, Gonzales FR, Mula RP, Gaur PM, Gonzales IC, Dar WD, *et al.* Chickpea (Garbanoz): An emerging crop for the rainfed and dryland areas of the Philippines. Information Bulletin No. 88. Patancheru (India): ICRISAT; 2011. p. 1-88.
13. Katoch R. Nutritional potential of rice bean (*Vigna umbellata*): An underutilized legume. Journal of Food Science. 2013;78(1):8-16.
14. Mahilane C, Singh V. Effect of zinc and molybdenum on growth, yield attributes, yield and protein in grain on summer blackgram (*Vigna mungo* L.). International Journal of Current Microbiology and Applied Sciences. 2018;7(1):1156-1162.
15. Marschner H. Mineral Nutrition of Higher Plants. London: Academic Press; 1986. p. 347-364.
16. Ram S, Katiyar TPS. Effect of sulphur and zinc on seed yield and protein content of summer mungbean under arid climate. International Journal of Science and Nature. 2013;4(3):563-566.
17. Mukund Gowda K, Halepyati AS, Koppalkar BG, Satyanarayana Rao. Yield, nutrient uptake and economics of pigeonpea (*Cajanus cajan* L. Millsp.) as influenced by soil application of micronutrients and foliar spray of macronutrients. Karnataka Journal of Agricultural Sciences. 2015;28(2):266-268.
18. Sharma AK, Sharma PK, Samuchia D, Karol A, Bairwa LK, Meena KS, *et al.* Effect of nitrogen and sulphur levels on quality parameter of mustard (*Brassica juncea* (L.)). Biological Forum-An International Journal. 2023;15(9):868-871.
19. Singh DK, Singh AK, Singh SK, Singh M, Shrivastava OP. Effect of balanced nutrition on yield and nutrient uptake of pea (*Pisum sativum* L.) under Indo-Gangetic plains of India. The Bioscan. 2015;10(3):1245-1249.
20. Singh O, Kumar S, Dwivedi A, Dhyani BP, Naresh RK. Effect of sulphur and iron fertilization on performance and production potential of urd bean (*Vigna mungo* (L.) Hepper) and nutrient removal under Inceptisols. Legume Research. 2016;39(6):946-954.
21. Singh RP, Dadhwal VK, Singh KP, Navalgund RR, Sharma R, Bairagi GD, *et al.* Effect of micronutrients on chickpea and pigeonpea in Ranchi. Journal of the Indian Society of Soil Science. 2005;33(2):307-313.
22. Sharma V, Abraham T. Response of blackgram (*Phaseolus mungo* L.) to nitrogen, zinc and farmyard manure. Legume Research-An International Journal. 2010;33(4):295-298.
23. Subramaniyan K, Lalaiselvan P, Arulmozhi N. Response of confectionery groundnut to micronutrients. Legume Research. 2001;24(2):139-140.
24. Surendra, Singh. Effect of sulphur on yields and S uptake by onion and garlic grown in acid Alfisols of Ranchi. Agricultural Science Digest. 2008;28(3):189-191.
25. Verma S, Choudhary MR, Yadav BL, Jakhar ML. Influence of vermicompost and sulphur on growth and yield of garlic (*Allium sativum* L.) under semi-arid climate. Journal of Spices and Aromatic Crops. 2013;22(1):20-23.