International Journal of Plant & Soil Science

Volume 37, Issue 12, Page 257-270, 2025; Article no.IJPSS.149586
ISSN: 2320-7035

Effect of Sulphur and Boron Application on Nutrient Uptake and Yield of Urdbean (*Vigna mungo*) Crop and its Residual Effect on Succeeding Toria (*Brassica campestris L. var. toria*)

Rajani Maurya [a], S.P. Pachauri [a*], Mubashir Sadiq V [b] and Rajan Shukla [c]

[a] Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India.
[b] Department of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi-110012, India.
[c] Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i125890

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/149586

Original Research Article

Received: 30/09/2025
Published: 22/12/2025

ABSTRACT

Aims: A field experiment was conducted to study the effect of different doses of sulphur and boron application on yield and nutrient uptake of urdbean crop and its residual effect on succeeding toria crop.

**Corresponding author: E-mail: satyapratappachauri@gmail.com;*

Cite as: *Rajani Maurya, S.P. Pachauri, Mubashir Sadiq V, and Rajan Shukla. 2025. "Effect of Sulphur and Boron Application on Nutrient Uptake and Yield of Urdbean (Vigna Mungo) Crop and Its Residual Effect on Succeeding Toria (Brassica Campestris L. Var. Toria)". International Journal of Plant & Soil Science 37 (12):257–270. https://doi.org/10.9734/ijpss/2025/v37i125890.*

Study Design: Randomised Block Design.
Place and Duration of Study: Field Experiment was conducted at Norman E. Borlaug Crop Research Centre, during Kharif and Rabi Season of 2021-22 and Lab analysis was done at Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand.
Methodology: There were 6 treatments and 4 replications of each treatment. Treatments included control (with neither boron nor sulphur application), 2 levels of boron (1 and 2 kg B ha^{-1}) and 3 levels of sulphur (20, 40 and 60 kg S ha^{-1}). Basal doses of abovementioned boron and sulphur levels were applied only to Urdbean crop and its residual effect was seen in succeeding Toria crop.
Results: Result analysis at p=0.05 revealed that Boron application at 1 kg ha^{-1} and 2 kg ha^{-1} causes significant, 11.58 % and 19.47 %, respective increase in urdbean grain yield and due to its residual effect toria oilseed grain yield also increases by 10.36 % and 10.90 % respectively in comparision to control. Similar, enhancements in grain yield (11.05 %, 20.00 % and 17.89%) and nutrient uptake were also noticed due to Sulphur application at 20, 40 and 60 kg ha^{-1} respectively to urdbean crop and residual effect of these sulphur levels also observed in yield and nutrient uptake of succeeding toria crop. On application of 2 kg B ha^{-1}, B uptake increased by 44.71 % in grains of urdbean crop and by 36.97 % in grains succeeding toria crop and on increasing dose of S application to 60 kg ha^{-1}, S uptake increased by 55.31 % in urdbean grains and by 52.63 % in grains of succeeding toria crop.
Conclusion: On increasing dose of B application to 2 kg per ha and S application to 60 kg ha^{-1} there is significant increase in yield and nutrient uptake of urdbean crop and positive residual effect of these doses can be seen in yield and nutrient uptake of succeeding toria crop. Since, there is no significant difference between 1 kg B ha^{-1} and 2 kg B ha^{-1} and also between 40 kg S ha^{-1} and 60 kg S ha^{-1}, with respect to grain yield and nutrient uptake of Urd bean-Toria crops, application of B at 1 kg ha^{-1} and S at 40 kg ha^{-1} is advisable in this region.

Keywords: Boron; micronutrient; nutrient management; nutrient uptake; residual effect; Sulphur.

1. INTRODUCTION

Pulses and oilseeds are very important components for diversification of cropping systems in India (Kumari et al., 2025). They are good source of protein and energy in our diet, especially in India where most of population is preferably vegetarian. Pulses are an important source of protein, macronutrients, micronutrients, carbohydrates as well as dietary fibers which gives many health benefits like controlling diabetes, lowering blood cholesterol level and heart diseases (Hall et al., 2017). Pulses contain minerals, vitamins A, B, E & C and antioxidants (Mudryj et al., 2014). India is leading producer of pulses in world (25.46 MT) but it is also leading in consumption and imports. Likewise, in India 30.24 Mha area is under oilseed cultivation and oilseed production is around 41.36 MT (Ministry of Agricultutre and Farmers Welfare, 2025) but still, a large part of edible oil in India is imported. Demand supply gap exists in case of both pulses and oilseeds in India (Agarwal & Devra, 2024). Since there is limited agricultural land available and there is competition for various crops and enterprises, productivity of both pulses and oilseeds has to be improved to meet out the yield gap. Pulses which contain 18 to 25% protein and oilseeds which contain approximately 9 kcal/g energy might be a potential solution to the problem of protein calorie malnutrition which India is facing today (Mazumdar et al., 2024).

Among the pulses, urdbean is an important crop in India which serve as source of carbohydrate, protein, fat, minerals, calcium, iron and fibre (Soharu et al., 2024). Urdbean can be cultivated in all three seasons as sole crop as well as mixed crop. It fits well in various multiple and intercropping system due to its short duration nature. Toria is generally not cultivated as main rabi crop beacause its yield potential is less but is taken as relay crop because of its short duration. Rabi season could be utilized by growing toria crop to achieve double cropping which contribute greatly to farmers income (Mookherjee et al., 2019). In addition to primary nutrients i.e. nitrogen, phosphorus and potassium, secondary nutrient like sulphur and micronutrient like boron play important role in production technology of pulses and oilseed crop and the response of these crops to application of S and B has been recorded (Ladohia et al., 2025) .

Now-a-days deficiency of sulphur in Indian soil has become a very common problem related to crop production. More than 41% of Indian soils are sulphur deficient. Continuous use of high analysis fertilisers combined with intensive cropping system and less use of organic manure has caused deficiency of sulphur in soil reserves. Approximately 10-30 % yield of oilseed crop is hampered by deficiency of sulphur. The requirement of sulphur of oilseed crops is more for growth and development than any other crop. About 10-25 kg sulphur is removed by oilseed crops and about 5-10 kg sulphur is removed by leguminous crops per hectare per year depending on soils, crops and environmental conditions (Singh and Singh, 2016). Sulphur is required in highest amount by crucifers followed by sesame and sunflower which in turn is followed by legumes. Sulphur is very important for synthesis of coenzymes which in turn are very important for fatty acid synthesis and application of sulphur increases oil content significantly.

Boron deficiency is increasing rapidly in soils of India and in crops deficiency of boron is more than the other essential micronutrient. Boron deficiency is generally not suspected in Indian soils but 33 % of Indian soils are boron deficient (Shukla and Behera, 2012) and adverse effect of boron deficiency is firstly seen on flowering and fruiting and therefore, on crop production and nutritional quality of crop. Next only to zinc, boron has become very important micronutrient in Indian agriculture (Arunkumar et al., 2018). Boron has an important role to play in plant nutrition and is recognised to be major yield limiting factor in pulse crops. Oilseed crops, also, are very sensitive to micronutrient deficiency, particularly, boron and hence, its deficiency adversely affects growth, yield and nutritional quality of oilseed crops. Both deficiency and overuse of boron fertilisers can have adverse effect on crops because there is very narrow range of deficiency and toxicity in case of both plants and soils. Henceforth, optimum supply of boron is must to obtain optimum growth and yield of crop.

Nutrient content and nutrient uptake in agricultural produce is adversely affected by deficiency of nutrients in soil. The soils which are deficient in S and B, produce crops that has low concentration of S and B in their produce. Therefore, its nutritional quality is adversely affected and its consumption leads to malnutrition problems in human and animal health. However, S and B application to soil might help in enhancing growth, yield and improving nutritional quality of crops. Response of crops to S and B application depends on multiple factors like crop type (cereals, pulses, oilseeds), available nutrient status of soil of particular location, yield level of particular crop and rate of sulphur and boron application. Therefore, optimum dose of S and B need to be established which must be soil-crop-agroecological condition specific. Sulphur and Boron application to soil prior to sowing of main crop, leaves its residual effect on succeeding crop. For effective nutrient management, this residual effect must be taken into consideration for improving both productivity and profitability. Generally, studies on effect of sulphur and boron application are restricted to one crop without consideration of either residual effect of both these nutrients (S and B) on succeeding crop. Therefore, in this study, urdbean-toria crop sequence was studied and residual effect emerging from S and B application to urdbean crop was studied on following toria crop.

2. MATERIALS AND METHODS

2.1 Site of the Experiment

Field experiment was conducted at E_1 block (Latitude-29˚01.453 N, Longitude-079º28.721 E and 215 m above mean sea level) of Norman E. Borlaug Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, during Kharif and Rabi Season of 2021-22.

2.2 Experimental Details

Field experiments were conducted with urdbean (*Vigna mungo*) crop followed by a crop of toria (*Brassica campestris var. toria*). Pant Urd 31 variety of blackgram and Uttara variety of toria crop was used for conducting the field experiment. There were 6 treatment combinations, which were replicated 4 times and the experiment was laid out in randomized block design. These treatment combinations were decided based on review of results of other researchers.

T_1 was treated as control in which RDF for respective crops was applied. Different doses of boron and sulphur in all other treatments (except control) was applied as basal dose in urdbean crop and residual effect of these boron and sulphur doses were studied in succeeding toria crop.

Table 1. Initial phyco-chemical characteristics of experimental soil (0-15 cm)

Parameters	Values	References
Mechanical Analysis Sand (%) Silt (%) Clay (%)	 70.4 20.0 09.6	Hydrometer method (Bouyoucos, 1936)
Textural class	Sandy loam	USDA, HANDBOOK 60
pH (1:2 Soil: water)	6.85	Jackson (1967)
EC (dSm^{-1}) (1:2 Soil: water)	0.22	Bower and Wilcox (1965)
Organic Carbon (%)	0.51	Walkley and Black (1934)
Mineralisable N (kg ha^{-1})	184.98	Subbiah and Asija (1956)
Available P (kg ha^{-1})	10.96	Olsen et al. (1954)
Available K (kg ha^{-1})	190.40	Neutral ammonium acetate method (Schollenberger and Simon, 1945)
Available S (ppm)	11.40	Turbidity method (Williams and Steinberg, 1969) and (Chesnin and Yien, 1951)
Hot $CaCl_2$ extractable B (ppm)	0.385	Hot Calcium Chloride extractable Boron method (Berger and Troug,1939)

Chart 1. Treatment details

Treatments	Urdbean crop	Toria crop
T_1	RDF* + 0 kg B ha^{-1} + 0 kg S ha^{-1}	RDF*
T_2	RDF* + 1 kg B ha^{-1} + 0 kg S ha^{-1}	RDF* + Residual effect of 1 kg B ha^{-1}
T_3	RDF* + 2 kg B ha^{-1} + 0 kg S ha^{-1}	RDF* + Residual effect of 2 kg B ha^{-1}
T_4	RDF* + 0 kg B ha^{-1} + 20 kg S ha^{-1}	RDF*+ Residual effect of 20 kg S ha^{-1}
T_5	RDF* + 0 kg B ha^{-1} + 40 kg S ha^{-1}	RDF* + Residual effect of 40 kg S ha^{-1}
T_6	RDF* + 0 kg B ha^{-1} + 60 kg S ha^{-1}	RDF* + Residual effect of 60 kg S ha^{-1}

** Recommended dose of fertilizer (RDF) for urd bean crop was 20 kg N ha^{-1}, 40 kg P ha^{-1} and 40 kg K ha^{-1} while for toria crop, it was 90 kg N ha^{-1}, 40 kg P ha^{-1} and 20 kg K ha^{-1}*

After field preparation, treatments were applied according to layout and seeds of urdbean crop was sown on 8th August, 2021. Crop was raised following recommended agronomic practices and it was harvested at physiological maturity stage of crop on 26 October, 2021. Yield attributes like number of pods per plant, number and test weight were recorded along with seed and stover yield of urd bean crop. After harvesting urdbean crop, field preparation and basal dose application of NPK at 90-40-20 kg ha^{-1} was done before sowing toria crop, to know the residual effect of sulphur and boron applied to preceeding urdbean crop, on succeeding toria crop. Sowing of toria crop was done on 2nd November, 2021 and it was harvested at physiological maturity stage on 9th February, 2022. Yield attributes like number of siliqua per plant and test weight were recorded along with seed yield and stover yield of toria crop.

2.3 Nutrient Analysis in Plant Material

After collecting plant samples, it was air dried for 3-4 days and then oven dried for 48 hrs at 600 C, followed by grinding. Wet digestion of plant material was done for S and dry ashing was done for B analysis. 2 mL of filterate collected after digesting the sample was taken in a 25 ml volumetric flask and S content was determined by turbidity method given by Williams and Steinberg, (1969) and Chesnin and Yien, (1951). 2 mL of filterate collected after dry ashing the sample was taken in plastic beaker and B content was determined by hot water extractable boron method by Berger and Troug, (1939).

$$\text{Extractable S (ppm)} = (S-B) \times \text{Dilution factor}$$

Where,

S- concentration of plant sample in ppm
B- concentration of blank sample in ppm
Extractable S (g kg^{-1}) = Extractable S (ppm) x 0.001

S uptake in grain (kg ha^{-1}) = grain yield (kg ha^{-1}) x S content in grain (g kg^{-1})/1000

S uptake in stover (kg ha^{-1}) = stover yield (kg ha^{-1}) x S content in stover (g kg^{-1})/1000

Extractable Boron (ppm) = (S-B) x Dilution factor

Where,

S- concentration of plant sample in ppm
B- concentration of blank sample in ppm

Boron uptake in grain (g ha^{-1}) = grain yield (kg ha^{-1}) x Boron content in grain (mg kg^{-1})/1000

Boron uptake in stover (g ha^{-1}) = stover yield (kg ha^{-1}) x Boron content in stover (mg kg^{-1})/1000

2.4 Oil Content

Oil content (%) analysis of toria seeds was done by using NIRFlex N500 instrument.

2.5 Statistical Analysis

Data was statistically analyzed by ANOVA technique. F test of significance at 5 percent probability was applied to compare the difference among treatments. Significant difference between means was recorded on basis of critical difference (C.D) as percent level of probability. OPSTAT software package was used for statistical analysis.

3. RESULTS AND DISCUSSION

3.1 Effect of S and B on Yield of Urdbean

3.1.1 Grain yield and stover yield

As it is evident from table 2, grain yield increases by 11.58 % and 19.47 % in treatments T_2 and T_3, respectively, as compared to T_1. This enhancement in grain yield on application of boron has been significant, when compared to T_1 but T_2 and T3 were found to be statistically at par with each other i.e. no significant difference with respect to grain yield has been noted when boron supply is increased from 1 kg ha^{-1} to 2 kg ha^{-1}. Such enhancement in grain yield can be mainly attributed to boron's functional role in development of flower, germination of pollen grain, growth of pollen tube, viability of pollen grain for proper pollination, development of seed, accumulation of dry matter and efficient translocation of assimilates to reproductive organs causing increase in number of pods and henceforth, grain yield. Also, application of boron makes quick availability of boron during entire growth period.

As it is also evident from table 2 that stover yield, significantly, increases by 10.51 % and 20.62 % in treatments T_2 and T_3 respectively, as compared to T_1. This increase in stover yield might be because of involvement of boron in stabilizing cell wall membrane, cell membrane structure, increased cell division, sugar transport, tissue differentiation, maintainance of xylem and phloem, metabolism of carbohydrate, protein, nucleic acid, auxin and phenol.

These results are supported by Naznin et al. (2020). They reported that increasing application of B upto 1 kg ha^{-1} increased seed yield and stover yield of black gram. These results are also in line with experiment conducted by Mishra et al. (2018) who reported that increasing dose of B upto 2 kg ha^{-1} increased grain yield of black gram. Ladohia et al. (2025) also reported that black gram yield was positively correlated with optimum boron and sulphur doses in blackgram.

As it is evident from Table 2, that grain yield increases by 11.05 %, 20.00 % and 17.89% in treatments T_4, T_5 and T_6 respectively, as compared to T_1. This enhancement in grain yield on increasing dose of sulphur application from 20 kg ha^{-1} to 60 kg ha^{-1} has been found to be significant when compared to T_1. It has been found that though there is significant increase from T_4 to T_5 but T_5 and T_6 are statistically at par with each other with respect to grain yield.

As it is also evident from Table 2, stover yield increases by 9.14 %, 19.07 % and 16.73 % in treatments T_4, T_5 and T_6 respectively, as compared to T_1. This enhancement in stover yield on increasing dose of sulphur application from 20 kg ha^{-1} to 60 kg ha^{-1} has been found to be significant when compared to T_1. It has been found that though there is significant increase from T_4 to T_5 but T_5 and T_6 are, statistically, at par with each other with respect to stover yield.

These results are in conformity with Patel et al. (2018) who reported that "application of 40 kg S ha^{-1} gave maximum seed yield and stover yield of black gram in vindhyan soil". Kumar et al. (2025) reported "application of 45 kg S ha^{-1} increased yield of urdbean crop. Bhat et al. (2025) reported similar significant increase in yield of soyabean on increasing dose of S application to 60 kg ha^{-1}".

Application of sulphur caused its greater availability to crop during its crop growth period. This increase in seed and stover yield due to S application might be because of involvement of S in photosynthesis and physiological processes like synthesis of S containing amino acids, cystine and methionine, as well as synthesis of chlorophyll. It also play vital role in metabolism of carbohydrate, protein and fat and also synthesis of coenzyme-A and vitamins like thiamine and biotine. Sulphur also helps in nodulation of legumes and biological nitrogen fixation.

3.1.2 Number of pods per plant

As it is evident from Table 3, number of pods per plant, significantly, increases by 11.45 % and 26.72 % in treatments T_2 and T_3 respectively, as compared to T_1. This increase in number of pods per plant on application of boron might have resulted due to supplementation of boron requirement for reproductive development.

It was reported by Naznin et al. (2020) that on increasing application of boron up to 1 kg ha^{-1} number of pods per plant of blackgram increase. Ladohia et al. (2025) reported an increase in number of pods per plant on increasing application of boron.

As it is also evident from Table 3, number of pods per plant increases by 12.21 %, 23.66 % and 17.56 % in treatments T_4, T_5 and T_6 respectively as compared to T_1. This enhancement in number of pods per plant on increasing dose of sulphur application from 20 kg ha^{-1} to 60 kg ha^{-1} has been found to be significant when compared to T_1. It has been found that though there is significant increase from T_4 to T_5 but T_5 and T_6 are statistically, at par with each other with respect to number of pods per plant.

These results were in agreement with Patel et al. (2018) who reported similar results in blackgram. They reported that application of S at 40 kg ha^{-1} gave highest number of pods per plant. Jaiswal et al. (2019) also reported that on increasing S application to 30 kg ha^{-1} number of pods per plant increases. This increase in number of pods per plant with increasing S application might have resulted due to better photosynthetic activity, in addition to better metabolite partitioning and nutrient translocation to developing structure. Bhat et al. (2025) reported similar significant increase in number of pods per plant on increasing dose of S application to 60 kg ha^{-1}.

3.1.3 Test weight

As it is evident from table 2, test weight increases by 10.26 % and 15.36 % in treatments T_2 and T_3 respectively as compared to T_1. This enhancement in test weight on application of boron has been significant, when compared to T_1 but T_2 and T3 were found to be statistically at par with each other i.e. no significant difference with respect to test weight has been noted when boron supply is increased from 1 kg ha^{-1} to 2 kg ha^{-1}.

Increase in test weight on application of boron has also been reported by Naznin et al. (2020) in blackgram. Tania et al. (2019) also reported that application of 1 kg B ha^{-1} brought significant increase in test weight compared to control. Since, boron is essentially required seed formation, sugar translocation and assimilate translocation to developing grain, its enhanced availability during crop growth through its soil application might have resulted in increased test weight on boron application. Giani et al., (2025) reported that increasing dose of B application to 3 kg B ha^{-1} recorded maximum test weight in greengram.

As it is also evident from table.1, test weight increases by 9.86 %, 13.37 % and 15.95 % in treatments T_4, T_5 and T_6 respectively as compared to T_1. However, T_4, T_5 and T_6 do not significantly differ from each other with respect to test weight. This increase in test weight in on increasing S application has also been reported by Jawahar et al. (2013) in blackgram. Sulphur application has helped greater dry matter accumulation and nitrogen accumulation in plants, which in turn is used by plants to produce more bold seeds. Kumar et al., 2024 reported increasing dose of sulphur application to 30 kg ha^{-1} enhanced test weight of black gram.

3.2 Effect of S and B on Nutrient Uptake by Urd Bean

3.2.1 S uptake in grain and stover

As it is evident from table 3 S uptake in grain significantly increases by 25.14 % and 39.66 % and S uptake in stover significantly increases by 19.81 % and 45.20 % in treatments T_2 and T_3 respectively, as compared to T_1. This result is in conformity with Kala et al. (2017) who reported an increase in S uptake in chickpea on increasing dose of boron application. This result was also supported by Laxmi et al. (2020) who reported an increase in S uptake by mungbean on boron application. Choudhary et al., (2025) reported an increase in nutrient uptake on increasing dose of B application.

Table 2. Effect of S and B on yield and yield attributes of urdbean

Treatments	Urd bean yield (Kg ha^{-1})		No. of pods per plant	Test weight (g)
	Grain	Stover		
T_1: RDF + 0 kg B ha^{-1} + 0 kg S ha^{-1}	1187.50	3212.50	32.75	35.29
T_2: RDF + 1 kg B ha^{-1} + 0 kg S ha^{-1}	1325.00	3550.00	36.50	38.91
T_3: RDF + 2 kg B ha^{-1}+ 0 kg S ha^{-1}	1418.75	3875.00	41.50	40.71
T_4: RDF + 0 kg B ha^{-1}+ 20 kg S ha^{-1}	1318.75	3506.25	36.75	38.77
T_5: RDF + 0 kg B ha^{-1}+ 40 kg S ha^{-1}	1425.00	3825.00	40.50	40.01
T_6: RDF + 0 kg B ha^{-1}+ 60 kg S ha^{-1}	1400.00	3750.00	38.50	40.92
SEm$\pm$	34.64	91.40	1.12	1.12
C.D. (*P*=0.05)	105.36	278.02	3.39	3.31

As it is also evident from table 3 that S uptake in grain increases by 31.84%, 55.87% and 55.31 % and S uptake in stover increases by 37.15%, 58.2% and 60.37% in treatments T_4, T_5 and T_6 respectively as compared to T_1. This enhancement in S uptake in grain and stover on increasing dose of sulphur application from 20 kg ha^{-1} to 60 kg ha^{-1} has been found to be significant when compared to T_1. It has been found that though there is significant increase from T_4 to T_5 but T_5 and T_6 are statistically at par with each other with respect to S uptake in grain and stover.

Kumar et al. (2025) reported application of 45 kg S ha^{-1} increased nutrient uptake of urdbean crop. Bhat et al. (2025) reported similar significant increase in S uptake of soyabean on increasing dose of S application to 60 kg ha^{-1}.

3.2.2 B uptake in grain and stover

As it is evident from table 3 boron uptake in grain significantly increases by 27.84% and 44.71% and boron uptake in stover significantly increases by 21.1 % and 42.61% in treatments T_2 and T_3 respectively as compared to T_1. It has also been found that boron uptake in grain and stover of urd bean significantly increases in treatment T_3 in comparision to T_2 also. This result was supported by Sayed et al., (2024) who reported an increase in B content and yield of grass pea on increasing dose of boron application.

As it is also evident from table 3 boron uptake in grain increases by 23.34%, 37.22% and 32.85% and boron uptake in stover increases by 14.62%, 27.74 % and 23.29% in treatments T_4, T_5 and T_6 respectively, as compared to T_1. It was also noted that though boron uptake significantly increased from T_4 to T_5 but T_5 and T_6 did not significantly differ from each other with respect to boron uptake in grain and stover.

This result was supported by Ganie et al. (2014) who reported an increase in boron uptake in seed and stover of french bean on increasing dose of sulphur application up to 45 kg ha^{-1}. This result was also supported by Kala et al. (2017) who reported an increase in boron uptake in seed and stover of chickpea on increasing level of sulphur application up to 40 kg ha^{-1}. This result was also supported by Choudhary et al., (2025) who reported an increase in nutrient uptake on increasing sulphur application dose.

3.3 Residual Effect of S and B on Yield and Oil Content of Toria

3.3.1 Grain yield and stover yield

As it is evident from table 4, grain yield increases by 10.36% and 10.90% and stover yield increases 13.42 % and 16.24%, as compared to control, due to residual effects of 1 kg B ha^{-1} and 2 kg B ha^{-1}, respectively. It has also been

Table 3. Effect of S and B on nutrient uptake by urdbean

Treatments	S uptake (kg ha^{-1})		B uptake (g ha^{-1})	
	grain	stover	grain	stover
T_1: RDF + 0 kg B ha^{-1} + 0 kg S ha^{-1}	1.79	3.23	23.35	37.27
T_2: RDF + 1 kg B ha^{-1} + 0 kg S ha^{-1}	2.24	3.87	29.85	45.13
T_3: RDF + 2 kg B ha^{-1}+ 0 kg S ha^{-1}	2.50	4.69	33.79	53.15
T_4: RDF + 0 kg B ha^{-1}+ 20 kg S ha^{-1}	2.36	4.43	28.80	42.72
T_5: RDF + 0 kg B ha^{-1}+ 40 kg S ha^{-1}	2.79	5.11	32.04	47.61
T_6: RDF + 0 kg B ha^{-1}+ 60 kg S ha^{-1}	2.78	5.18	31.02	45.95
SEm$\pm$	0.07	0.12	0.80	1.23
C.D. (p=0.05)	0.20	0.38	2.43	3.74

observed that though grain yield significantly increases due to residual effect of both 1 kg B ha^{-1} and 2 kg B ha^{-1} compared to control but there was no significant difference between residual effect of 1 kg B ha^{-1} and 2 kg B ha^{-1} with respect to grain yield and stover yield of toria.

This result shows that boron applied at 1 kg ha^{-1} and 2 kg ha^{-1} to urd bean crop was sufficient to meet the boron requirement of succeeding toria crop. This shows that one boron application to urd bean crop is sufficient to to improve the yield of successive toria crop in following season and boron application can be avoided in following season.

This result was supported by Prashantha et al. (2019), who observed residual effect of zinc and boron on yield of groundnut in finger millet-groundnut cropping system and reported an increase in yield of groundnut with repect to control due to residual effect of boron. Residual effect of micronutrient on yield and nutrient uptake of succeeding crop was also confirmed by Pravalika et al., (2025). Rehman et al., (2013) confirmed the residual effect of boron feriliser on yield of succeeding field crop.

As it is also evident from table 4, grain yield increases by 10.37 %, 23.25 % and 23.81 % and stover yield increases by 18.56 %, 30.50 and 30.76 %, as compared to control, due to residual effects of 20 kg S ha^{-1}, 40 kg S ha^{-1} and 60 kg S ha^{-1}, respectively. It has also been observed that residual effects at 20 kg S ha^{-1}, 40 kg S ha^{-1}, 60 kg S ha^{-1} were statistically different with respect to control but only residual effects of 20 kg S ha^{-1} and 40 kg S ha^{-1} statistically differed from each other and residual effects of 40 kg S ha^{-1} and 60 kg S ha^{-1} were statiscally at par with each other with respect to grain yield and stover yield.

Residual effect of sulphur on yield of succeeding crop was also confirmed by Rathore et al., (2024). Tarafdar et al. (2019) also observed an increase in seed and stover yield of mustard due to residual effect of different levels of sulphur in rice-mustard-green gram cropping system. This result is in line with Shekhawat and Shivay (2012) who reported an increase in grain and stover yield of green gram due to residual effect of different level of sulphur and boron in sunflower-green gram cropping system.

3.3.2 Number of siliqua per plant

As it is evident from table 4, number of siliqua per plant increases by 8.16 % and 10.74 %, as compared to control, due to residual effects of 1 kg B ha^{-1} and 2 kg B ha^{-1}, respectively. It has also been observed that though number of siliqua per plant increases due to residual effect of both 1 kg B ha^{-1} and 2 kg B ha^{-1} compared to control but there was significant difference with respect to number of siliqua per plant of toria only due to residual effect of 2 kg B ha^{-1}.

This result was in line with Prashantha et al. (2019), who reported an increase in number of pods per plant in groundnut due to residual effect of boron in finger millet-groundnut cropping system. Similar results on yield attributes of mustard was obtained by Pant et al. (2022) due to residual effect of sulphur and boron.

As it is also evident from table 5, number of siliqua per plant increases by 15.08 %, 24.94 % and 30.85 %, as compared to control, due to residual effects of 20 kg S ha^{-1}, 40 kg S ha^{-1} and 60 kg S ha^{-1}, respectively. It has also been observed that residual effects at 20 kg S ha^{-1}, 40 kg S ha^{-1}, 60 kg S ha-^{1} were statistically different with respect to control but only residual effects of 20 kg S ha^{-1} and 40 kg S ha^{-1} statistically differed from each other and residual effects of 40 kg S ha^{-1} and 60 kg S ha^{-1} were statistically at par with each other with respect to plant height of toria. This result is in line with Tarafdar et al. (2019) who reported significant increase in number of siliqua per plant due to residual effect of sulphur at 45 kg ha^{-1} in rice-mustard-green gram cropping system.

3.3.3 Test weight

As it is evident from table 4, test weight, significantly, increases by 13.78 % and 15.65 %, as compared to control, due to residual effects of 1 kg B ha^{-1} and 2 kg B ha^{-1}, respectively. This result was in line with Prashantha et al. (2019), who reported an increase in 100 kernel weight of groundnut, with respect to control, due to residual effect of boron application.

As it is also evident from table 4, test weight of toria, significantly, increases by 19.17 %, 23.64 % and 27.16 %, as compared to control, due to residual effects of 20 kg S ha^{-1}, 40 kg S ha^{-1} and 60 kg S ha^{-1}, respectively. This result is in line with Lakshman et al. (2017) who reported significant increase in test weight of mustard due to residual effect of sulphur at 45 kg ha^{-1} in soyabean-mustard cropping sequence.

3.3.4 Oil content (%)

As it is evident from table 4, oil content, significantly, increases by 6.62 % and 10.05 %, as compared to control, due to residual effects of 1 kg B ha^{-1} and 2 kg B ha^{-1}, respectively. Increase in oil content of mustard on increasing dose of boron application was also reported by Jaiswal et al. (2015). This might be due to Boron's role in bio-synthesis of fatty acid and oil (Mallick and Raj, 2015).

As it is also evident from table 4, oil content of toria, significantly, increases by 13.29 %, 18.23 % and 19.71 %, as compared to control, due to residual effects of 20 kg S ha^{-1}, 40 kg S ha^{-1} and 60 kg S ha^{-1}, respectively. This result is in line with Lakshman et al. (2017) who reported significant increase in oil content of mustard due to residual effect of different dose of sulphur applied to preceeding soyabean crop in soyabean-mustard cropping system. Mustard oil synthesis requires glucosinolate, which in turn in constituted by sulphur. Also, lipoic acid and CoA synthesis is favoured by sulphur application, which is responsible for increasing oil content (George and Mathew, 2013).

Sulphur application at different doses to crop leaves residual effect in proportionate amount for succeeding crop as reported by Singh and Pandey (2018) and Singh et al. (2018) and increasing dose of sulphur enhances growth and yield of oilseeds as reported by Rajput et al. (2018) and Sahoo et al. (2017). Henceforth, increasing dose of sulphur application to urdbean crop might have increased growth and yield of succeeding toria crop in proportionate amount.

Boron application at different doses to crop leaves residual effect in proportionate amount for succeeding crop as reported by Ahmed et al. (2018), and Chanchal et al. (2020) and increasing dose of boron enhances growth and yield of oilseeds as reported by Padasalagi et al. (2019), Masum et al. (2019) and Jyothi et al. (2018). Henceforth, increasing dose of boron application to urdbean crop might have increased growth and yield of succeeding toria crop in proportionate amount.

3.4 Residual Effect of S and B on Nutrient Uptake by Toria

3.4.1 S uptake in grain and stover

As depicted in table 5, S uptake in grain, significantly, increases by 16.45 % and 22.37 % and S uptake in stover, significantly, increases by 20.2 % and 25.12 % with respect to control due to residual effect of 1 kg B ha^{-1} and 2 kg B ha^{-1} respectively. Also, S uptake in grain, significantly, increases by 28.95 %, 52.63 %, and 57.89 %

Table 4. Residual effect of S and B on yield and oil content of toria

Treatments	Toria yield (kg ha^{-1})		No. of siliqua per plant	Test weight (g)	Oil content (%)
	grain	stover			
T_1: RDF (Control)	596.88	1266.25	75.58	3.13	37.03
T_2: RDF + Residual effect of 1 kg B ha^{-1}	658.75	1437.50	81.75	3.46	39.48
T_3: RDF + Residual effect of 2 kg B ha^{-1}	661.98	1471.88	83.70	3.62	40.75
T_4: RDF + Residual effect of 20 kg S ha^{-1}	667.00	1501.25	86.98	3.73	41.95
T_5: RDF + Residual effect of 40 kg S ha^{-1}	735.63	1652.48	94.43	3.87	43.78
T_6: RDF + Residual effect of 60 kg S ha^{-1}	739.00	1655.75	98.90	3.98	44.33
SEm$\pm$	19.17	38.97	2.27	0.10	0.49
C.D. (p=0.05)	58.32	118.54	6.90	0.32	1.48

Table 5. Residual effect of S and B on nutrient uptake by toria

Treatments	S uptake (kg ha^{-1})		B uptake (g ha^{-1})	
	grain	stover	grain	stover
T_1: RDF (Control)	1.52	2.03	10.90	12.16
T_2: RDF + Residual effect of 1 kg B ha^{-1}	1.77	2.44	14.15	16.76
T_3: RDF + Residual effect of 2 kg B ha^{-1}	1.86	2.54	14.93	20.01
T_4: RDF + Residual effect of 20 kg S ha^{-1}	1.96	2.73	12.42	15.56
T_5: RDF + Residual effect of 40 kg S ha^{-1}	2.32	3.15	15.70	18.66
T_6: RDF + Residual effect of 60 kg S ha^{-1}	2.40	3.23	15.87	19.21
SEm$\pm$	0.06	0.08	0.47	0.46
C.D. (p=0.05)	0.18	0.23	1.42	1.40

and S uptake in stover, significantly, increases by 34.48 %, 55.17 % and 59.11 % due to residual effect of 20 kg S ha^{-1}, 40 kg S ha^{-1} and 60 kg S ha^{-1}, respectively. However, S uptake in grain and stover of toria due to residual effect of 40 kg S ha^{-1} and 60 kg S ha^{-1} were, statistically, at par with each other.

This result is in conformity with Shekhawat and Shivay (2012), who reported an increase in sulphur uptake in grain and stover of green gram due to residual boron and sulphur effect in sunflower-greengram cropping system. Residual effect of sulphur fertilization on yield and nutrient content of succeeding crop was also supported by Mandi et al., (2024).

3.4.2 B uptake in grain and stover

As depicted in table 5, B uptake in grain, significantly, increases by 29.82 % and 36.97 % and B uptake in stover, significantly, increases by 37.83 % and 64.56 % with respect to control due to residual effect of 1 kg B ha^{-1} and 2 kg B ha^{-1} respectively. However, B uptake in grain due to residual effects of 1 kg B ha^{-1} and 2 kg B ha^{-1} were, statistically, at par with each other.

Also, B uptake in grain, significantly, increases by 13.94 %, 44.04 %, and 45.6 % and B uptake in stover, significantly, increases by 27.96 %, 53.35 % and 57.98 % due to residual effect of 20 kg S ha-1, 40 kg S ha^{-1} and 60 kg S ha^{-1} respectively. However, B uptake in grain and stover due to residual effect of 40 kg S ha^{-1} and 60 kg S ha^{-1} were statistically, at par, with each other.

This result is in conformity with Shekhawat and Shivay (2012), who reported an increase in boron uptake in grain and stover of green gram due to residual boron and sulphur effect in sunflower-greengram cropping system. Pant et al. (2022) also report an increase in boron uptake of succeeding mustard crop on increasing dose of boron and sulphur application to preceding crop.

4. CONCLUSION

Boron application at 1 kg ha^{-1} and 2 kg ha^{-1} causes significant increase in grain yield and nutrient (S, B) uptake by urd bean crop. It also shows significant residual effect, with respect to grain yield and nutrient (S, B) uptake by succeeding toria crop. Since, there is no significant difference with respect to grain yield, at 1 kg ha^{-1} and 2 kg ha^{-1}, in urd bean-toria crop, it is advisable to apply boron at 1 kg ha^{-1}. Sulphur application at 20 kg ha^{-1}, 40 kg ha^{-1} and 60 kg ha^{-1} causes significant increase in grain yield and nutrient (S, B) uptake by urd bean crop. It also shows significant residual effect, with respect to grain yield and nutrient (S, B) uptake by succeeding toria crop. Since, there is no significant difference with respect to grain yield, at 40 kg ha^{-1} and 60 kg ha^{-1}, in urd bean-toria crop, it is advisable to apply sulphur at 40 kg ha^{-1}.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

ACKNOWLEDGEMENTS

We are grateful to ICAR for funding research and analysis through NTS fellowship to author.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Agarwal, D., & Devra, S. J. (2024). Pulses in India: Comprehensive analysis of production, challenges, and strategic vision for 2030. *Journal of Experimental Agriculture International*, *46*(11), 293-304. https://doi.org/10.9734/jeai/2024/v46i113053

Ahmed, N., Masood, S., Abid, M., Mustafa, G., Ali, M. A., Ahmad, S., & Qayyum, M. F. (2018). Determination of Residual and Cumulative Boron Requirements for Cotton and Wheat Crops Grown Under Calcareous Soil Conditions. *Communication in Soil Science and Plant Analysis,* *49*(9), 1092-1098. https://doi.org/10.1080/00103624.2018.1448859

Arunkumar, B.R., Thippeshappa, G.N., Anjali, M.C., & Prashanth, K.M. (2018). Boron: A critical micronutrient for crop growth and productivity. *Journal of Pharmacognosy and Phytochemistry*, *7*(2): 2738-2741. https://www.researchgate.net/publication/344402191_Boron_A_critical_micronutrient_for_crop_growth_and_productivity

Berger, K. C., & Truog, E. (1939). Boron determination in soils and plants. *Industrial & Engineering Chemistry Analytical Edition*, *11*(10), 540-545. https://doi.org/10.1021/ac50138a007

Bhat, T. A., Nazir, A., Jamsheed, B., Jan, B., Shah, Z. A., Dar, E. A., & Ayman, E. S. (2025). Quadratic response assessment of gypsum and elemental sulphur on the yield and S use efficiency for soybean. *Scientific Reports*, *15*(1), 38515. https://doi.org/10.1038/s41598-025-97011-5

Bouyoucos, G. J. (1936). Directions for making mechanical analysis of soils by the hydrometer method. *Soil Science*, *42*(3), 225–230. https://doi.org/10.1097/00010694-193609000-00007

Bower, C. A., & Wilcox, L. V. (1965). Soluble salts. In C. A. Black *et al.* (Eds.), Methods of soil analysis: Part 2 Chemical and microbiological properties (pp. 433–451). American Society of Agronomy. https://doi.org/10.2134/agronmonogr9.2

Chanchal, A., Singh, S. K., Patra, A., & Jatav, S. S. (2020). Direct and Residual Effect of Boron Application on Yield and Nutrients Content under Rice–wheat Cropping System. *Current Journal of Applied Science and Technology*. https://doi.org/10.9734/cjast/2020/v39i230492

Chesnin, L., & Yien, C. H. (1951). Turbidimetric Determination of Available Sulfates. *Soil Science Society of America Proceedings*, *15*, 149–151. https://doi.org/10.2136/sssaj1951.036159950015000C0032x

Choudhary, S., Singh, S., Singh, A., & Sharma, N. K. (2025). Sulfur and boron fertilization: impact on yield, quality and nutrient use-efficiencies of lentil (Lens culinaris Medik.) in an Alfisol of Vindhyan region. *Journal of Plant Nutrition*, 1-19. https://doi.org/10.1080/01904167.2025.2517239

Ganie, M. A., Akhter, F., Najar, G. R., Bhat, M. A., & Mahdi, S. S. (2014). Influence of sulphur and boron supply on nutrient content and uptake of French bean (Phaseolus vulgaris L.) under inceptisols of North Kashmir. *African Journal of Agricultural Research, 9*(2), 230-239. http://www.academicjournals.org/article/article1389260524_Ganie%20et%20al.pdf

George, S., & Mathew, J. (2013). Synergistic-influence of sulphur and boron on enhancing the productivity of sesame (Sesamum indicum L.) grown in an entisol of Kerala. *Journal of the Indian Society of Soil Science, 61*(2), 122-127. https://epubs.icar.org.in/index.php/JISSS/article/view/32794

Giani, M. N., Khanm, F., Hasan, M., Huq, S. M. I., & Ahmad, S. A. (2025). Performance of boron on mung bean (Vigna radiata L.) productivity. *Journal of Biodiversity Conservation and Bioresource Management*, *10*(2), 19–30. https://doi.org/10.3329/jbcbm.v10i2.82241

Hall, C., Hillen, C., & Garden Robinson, J. (2017). Composition, nutritional value, and health benefits of pulses. *Cereal Chemistry, 94*(1), 11-31. https://doi.org/10.1094/CCHEM-03-16-0069-FI

Jackson, M. L. (1967). Soil chemical analysis. *Prentice Hall of India (P) Ltd., New Delhi, India.* (pp. 183-192). https://archive.org/details/soilchemicalanal030843mbp

Jaiswal, A. D., Singh, S. K., Singh, Y. K., Singh, S., & Yadav, S. N. (2015). Effect of Sulphur and Boron on Yield and Quality of Mustard (Brassica juncea L.) Grown on Vindhyan Red Soil. *Journal of the Indian Society of Soil Science, 63*(3), 362-364. https://doi.org/10.5958/0974-0228.2015.00047.X

Jaiswal, J. S., Kashyap, Y. and Bharve, V. (2019). Response of black gram (*Vigna mungo* L.) to graded doses of Sulphur under rainfed conditions*. Journal of pharmacogosy and Phytochemistry 2*, 124-127. https://www.phytojournal.com/archives/2019/vol8issue2S/PartD/Sp-8-2-28-194.pdf

Jawahar, S., Vaiyapuri, V., Suseendran, K., Kalaiyarasan, C., & Sriramachandrasekharan, M. V. (2013). Effect of sources and levels of sulphur on growth and yield of rice fallow blackgram (*Vigna mungo*). *International Research Journal of Chemistry*. https://petsd.org/ojs/index.php/irjc/article/download/23/16

Jyothi, P., Anjaiah, T., Murthy, I. Y. L. N., Naik, R., & Hussain, S. A. (2018). Seed Yield and Nutrient Uptake of Sunflower (Helianthus annuus L.) as Influenced by Different Levels of Boron and Potassium in Sandy Loam Soil*. International Journal of*

Current Microbiology and Applied Sciences, 7(7), 3684-3692. https://doi.org/10.20546/ijcmas.2018.707.425

Kala, D. C., Dixit, R. N., Meena, S. S., Nanda, G., & Pal, R. K. (2017). Effect of graded doses of sulphur and boron on yield attributes and nutrient uptake by chickpea. *International Journal of Current Microbiology and Applied Sciences, 6*(6), 55-60. https://doi.org/10.20546/ijcmas.2017.606.006

Kumar, P., Tiwari, J. K., Syed, S., & Singh, D. (2025). Effect of Different Doses of Sulphur and Vermicompost on Yield and Nutrient Uptake of Black Gram (*Vigna mungo* L.). *International Journal of Environment and Climate Change, 15*(12), 52–58. DOI:10.9734/ijecc/2025/v15i125146

Kumar, S., Singh, K., & Dawson, J. (2024). Effect of Sulphur and Zinc on Growth and Yield of Black Gram (Phaseolus mungo L.). *International Journal of Plant & Soil Science*, *36*(5), 984-988. DOI: 10.9734/IJPSS/2024/v36i54594

Kumari, V. V., KA, G., Chandran MA, S., Shankar, A. K., S, S., Kumar, M., & Singh, V. K. (2025). Diversified legume-oilseed cropping system for synergistic enhancement of yield and water use efficiency in rainfed areas of semi-arid tropics. *PloS one*, *20*(2), e0317373. https://doi.org/10.1371/journal.pone.0317373

Ladohia, S., Rana, N., Sharma, S., Kumar, R., Mehta, S. & Choudhary, S. (2025). Performance of Sulphur and Boron on Growth and Yield of Black Gram (*Vigna mungo* L.). *Agricultural Science Digest*, 1-6. DOI: 10.18805/ag. D-6335.

Lakshman, K., Vyas, A. K., Shivakumar, B. G., Rana, D. S., Layek, J., & Munda, S. (2017). Direct and residual effect of sulphur fertilization on growth, yield and quality of mustard in a soybean–mustard cropping system. *International Journal of Current Microbiology and Applied Sciences,* 6(5), 1500–1512. https://doi.org/10.20546/ijcmas.2017.605.163

Laxmi, S., Meena, R., Meena, R.N., Patel, M.K., Paul, A., Dubey, A., & Meena, K. (2020). Effect of Graded Dose of Sulfur and Boron on Yield and Nutrient Uptake by Mungbean (Vigna radiata). *Environment and Ecology, 38*(1), 1-5. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20203189912

Mallick, R. B., & Raj, A. (2015). Influence of phosphorus, sulphur and boron on growth, yield, nutrient uptake and economics of rapeseed (*Brassica campestris* L. *var*. yellow sarson). *International Journal of Plant, Animal and Environmental Sciences, 5*(3), 22-27. http://ijpaes.com

Mandi, S., Shivay, Y. S., Prasanna, R., Nayak, S., Baral, K., Reddy, K. S., & Borate, R. B. (2024). Insights into the Response of Elemental Sulfur Fertilization on Crop Yield and Nutritional Quality of Durum Wheat. *Journal of Soil Science and Plant Nutrition*, *24*(4), 8306-8320. https://doi.org/10.1007/s42729-024-02116-x

Masum, M. A., Miah, M. N. H., Islam, M. N., Hossain, M. S., Mandal, P., & Chowdhury, A. P. (2019). Effect of boron fertilization on yield and yield attributes of mustard var. BARI Sarisha-14. *Journal of Bioscience and Agriculture Research, 20*(02), 1717-1723. https://doi.org/10.18801/jbar.200119.209

Mazumdar, S. D., Afari-Sefa, V., Selvaraj, A., Durgalla, P., Seetha, A., Nedumaran, T., & Bose, D. (2024). Effectiveness of Millet-Pulse-Groundnut Based Formulations in Improving the Growth of Pre-school Tribal Children in Telangana State, India. *Preprints*, 1-16. https://doi.org/10.20944/preprints202401.0757.v2

Ministry of Agriculture & Farmers Welfare. (2025). *Annual report 2024-25*. Government of India. https://www.agriwelfare.gov.in/Documents/HomeWhatsNew/AR_Eng_2024_25.pdf

Mishra, U. S., Sharma, D., & Raghubanshi, B. P. S. (2018). Effect of zinc and boron on yield, nutrient content and quality of blackgram (Vigna mungo L.). *Research on Crops, 19*(1), 34-37. https://doi.org/10.5958/2348-7542.2018.00005.0

Mookherjee, S., et al. (2019). Gap Analysis of Resource Conservation Protocol on *Brassica campestris var. toria* through Farmers' Participatory Front Line Demonstration Under Old Alluvial Zone of West Bengal, India. *International Journal of Agriculture Sciences, 11*(14), 8821-8823. https://doi.org/10.9735/0975-3710.11.14.8821

Mudryj, A. N., Yu, N., & Aukema, H. M. (2014). Nutritional and health benefits of pulses. *Applied Physiology, Nutrition, and Metabolism, 39*(11), 1197-1204. https://doi.org/10.1139/apnm-2013-0557

Naznin, F., Hossain, M. A., Khan, M. A., Islam, M. A., & Rahman, A. K. M. H. (2020). Effect of Boron on Growth, Yield and Nutrient Accumulation in Black Gram. *The Agriculturists, 18*(2), 34-43. https://www.researchgate.net/publication/347340000_Effect_of_Boron_on_Growth_Yield_and_Nutrient_Accumulation_in_Black_Gram

Naznin, F., Hossain, M. A., Khan, M. A., Islam, M. A., & Rahman, A. K. M. H. (2020). Effect of Boron on Growth, Yield and Nutrient Accumulation in Black Gram. *The Agriculturists, 18*(2), 34-43. http://www.banglajol.info/index.php/AGRIC

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (Circular No. 939). *U.S. Department of Agriculture.* https://archive.org/download/estimationofavai939olse/estimationofavai939olse.pdf

Padasalagi, R. M., Lalitha, B. S., Jayadeva, H. M., & Raddy, G. (2019). Effect of sulphur and boron on growth and yield of sesame (*Sesamum indicum* L.). *Journal of Pharmacognosy and Phytochemistry, 8*(6), 1426-1431. https://www.phytojournal.com/archives/2019/vol8issue6/

Pant, C., Pachauri, S., Srivastava, A., SINGH, V., & SHUKLA, A. (2022). Residual effect of varying levels of sulphur, zinc and boron on yield, yield attributing characters, nutrient uptake and quality in mustard (*Brassica juncea* L.) grown after cluster bean in a Mollisol. *Annals of Plant and Soil Research*, *24*(4), 636-645. https://doi.org/10.47815/apsr.2022.10221

Patel, A. K., Nath, T., Prajapati, A., Singh, V. K., & Pandey, S. K. (2018)**.** Effect of doses and sources of sulphur on growth and yield of black gram (*Vigna mungo* L.) under rainfed condition of Vindhyan Soil. *Journal of pharmacogosy and Phytochemistry*, *1*, 91-94. https://www.phytojournal.com/archives/2018/vol7issue1S/PartB/SP-7-1-273-184.pdf

Prashantha, G. M., Prakash, S. S., Umesha, S., Chikkaramappa, T., Subbarayappa, C. T., & Ramamurthy, V. (2019). Direct and residual effect of zinc and boron on yield and yield attributes of finger millet–groundnut cropping system. *International Journal of Pure and Applied Biosciences, 7*(1), 124-134. https://doi.org/10.18782/2320-7051.7307

Pravalika, K. M., Yogananda, S. B., Prakash, S. S., Fathima, P. S., & Thimmegowda, P. (2025). Response of Greengram (*Vigna radiata L*.) as Succeeding Crop to Residual Effect of Micronutrients Mixture Administered in Preceding Sweet corn [*Zea mays* (L.) *Saccharata*]. *Legume Research: An International Journal*, *48*(2). DOI: 10.18805/LR-5417

Rajput, R. K., Singh, S., Varma, J., Rajput, P., Singh, M., & Nath, S. (2018). Effect of different levels of nitrogen and sulphur on growth and yield of Indian mustard (Brassica juncea (L.) Czern and Coss.) in salt affected soil. *Journal of Pharmacognosy and Phytochemistry, 7*(1), 1053–1055. https://www.jpp.com/abstract/effect-of-different-levels-of-nitrogen-and-sulphur-on-growth-and-yield-of-indian-mustard-brassica-juncea-l-czern-and-coss-in-salt-affected-soil-1000.html

Rathore, S. S., Sharma, K. C., Shekhawat, K., Babu, S., Sanketh, G. D., Singh, V. K., & Singh, H. (2024). Sulfonated nitrogen and added-sulfur sources influence productivity, quality, and nutrient acquisition of soybean-wheat cropping system. *Heliyon*, *10*(5). https://doi.org/10.1016/j.heliyon.2024.e26815

Rehman, H. U., Iqbal, Q., Farooq, M., Wahid, A., Afzal, I., & Basra, S. M. A. (2013). Sulphur application improves the growth, seed yield and oil quality of canola. *Acta Physiologiae Plantarum, 35*(10), 2999-3006. https://doi.org/10.1007/s11738-013-1331-9

Sahoo, G. C., Biswas, P. K., & Santra, G. H. (2017). Effect of different sources of sulphur on growth, productivity and oil content of Brassica campestris var. toria in the red Soil of Odisha. *International journal of agriculture environment and biotechnology, 10*(6), 689-694. https://doi.org/10.5958/2230-732X.2017.00085.7

Sayed, M., Hosen, M., Rahman, M. H., Morium, M., Islam, M. R., Kubra, M. K., & Islam, M. S. (2024). Effect of boron and zinc on growth, yield attributes, yield and nutrient bio-fortification of grass pea (*Lathyrus sativus* L.) in old Himalayan piedmont plain. *Applied Ecology & Environmental Research*, *22*(3). http://dx.doi.org/10.15666/aeer/2203_2277 2305

Schollenberger, C. J., & Simon, R. H. (1945). Determination of exchange capacity and exchangeable bases in soil—Ammonium acetate method. *Soil Science*, *59*(1), 13–24. http://dx.doi.org/10.1097/00010694-194501000-00004.

Shekhawat, K., & Shivay, Y. S. (2012). Residual effects of nitrogen sources, sulfur and boron levels on mungbean (Vigna radiata) in a sunflower (Helianthus annuus)–mungbean system. *Archives of Agronomy and Soil Science, 58*(7), 765-776. https://doi.org/10.1080/03650340.2010.546 786

Shukla, A. K., & Behera, S. K. (2012). Micronutrient fertilizers for higher productivity. *Indian Journal of Fertilisers, 8*(4), 100-117. http://www.faidelhi.org

Singh, S., & Singh, S. K. (2016). Use of indigenous sources of sulphur in soils of eastern India for higher crops yield and quality- A review. *Agricultural Reviews, 37*(2), 117-124. https://doi.org/10.18805/ar.v0iof.9626

Singh, S., Singh, V., Shukla, R. D., & Dubey, D. (2018). Influences of sulphur and zinc levels on soybean and residual effect on succeeding crop in soybean-wheat cropping system. *International Journal of Chemical Studies, 6*(3), 1130-1134. https://www.chemijournal.com/archives/20 18/vol6issue3/PartP/6-3-10-100.html

Singh, V. & Pandey, M. (2018). Direct effect of sulphur and zinc on productivity, quality and nutrient uptake by pearl millet (*Pennisetum glaucum*) and their residual effect on succeeding wheat (*Triticum aestivum*) in pearl millet–wheat crop sequence. *Annals of Plant Soil Research, 20*(3), 233-238. https://gkvsociety.com/control/uploads/383 5874.pdf

Soharu, A., Mittal, R. K., Sood, V. K., Dhaliwal, Y. S., & Sharma, S. (2024). Evaluation of Proximate Composition, Cooking Quality, and Texture Profile Analysis in Himalayan Landraces of Black Gram (*Vigna mungo*). *Plant Foods for Human Nutrition*, *79*(4), 819-826. https://doi.org/10.1007/s11130-024-01227-1

Subbiah, B. V., & Asija, G. L. (1956). A rapid method for the estimation of nitrogen in soil. *Current Science, 26*, 259-260.

Tania, S. A., Uddin, F. M. J., & Sarkar, M. A. R. (2019). Responses of selected mungbean (*Vigna radiata* L.) varieties to boron fertilization. *Fundamental and Applied Agriculture*. https://doi.org/10.5455/faa.815

Tarafdar, J. C., Sen, P., Dolui, & A. K. (2019). Effect of Sulphur on Yield and Yield Attributes of Rice and Subsequent its Residual Effect on Mustard and Green Gram Crops. *Indian Agriculturist, 63*(1), 1-9. https://www.indianagriculturist.co.in/wp-content/uploads/2025/06/VOL_63__NO._1 __2019.pdf

Walkley, A., & Black, I. A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Science*, *37*(1), 29–38. https://www.scirp.org/reference/Reference sPapers?ReferenceID=186446

Williams, C. H., & Steinbergs, A. (1969). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research*, *10*(3), 340-352. https://doi.org/10.1071/AR9590340

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/149586