Effect of sulphur nutrition on the production potential of *Brassica spp* - A review

Abstract

This paper examines the effect of sulphur on yield and quality of oilseed *Brassica spp.* Sulphur is a crucial nutrient for rapeseed since it is linked to productivity and a number of quality characteristics. It is necessary for the production of protein along with nitrogen and contains considerably higher sulfur-containing amino acids in rapeseed than in other crop plants. Brassicas also need sulphur in order to produce the sulfur-containing chemicals called glucosinolates. Rapeseed has a higher sulphur requirement than other crops, with 20-30 kg S ha-1 removed in the seed, whereas cereals remove only 5-15 kg ha-1. As a result, oilseed rape is especially vulnerable to sulphur shortages. Sulphur is required for the production of chlorophyll within the plant, and deficiency symptoms begin with a slight paling of the leaves and progress to interveinal chlorosis.

Keywords: Growth, *Brassica spp*, Sulphur, Yield, Quality

1. Introduction

"Rapeseed (*Brassica napus*) is an important oilseed crop of India and its oil is mainly used as edible oil. In India, *campestris* is mainly cultivated and another species *B. juncea* is also cultivated for edible oil" (Kaul and Das, 1986). "Edible oil plays a very important role in human nutrition. As a high-energy component of food, edible oils are important for meeting the calorie requirements. India has been facing acute shortage of edible oil for the last several decades. Internal production can meet only about 21% of consumption. To meet the growing demand of oilseed, it is urgent to ensure its higher production. It is almost impossible to increase production by increasing area because of crop competitions" (Egesel *et al.*, 2009).

"Production per unit area can be increased nevertheless by adopting improved technology and inputs. Mustard *(Brassica nigra)* is responsive to sulphur in comparison to other crops. *Brassica jucia* crops in general have high sulphur requirement owing to higher seed and oil yield. Mustard also requires high inputs of sulphur. Sulphur is the key component of balanced nutrient application for higher yields and superior quality produce in numerous crops" (Ahmad *et al.*, 2007).

"In general, about 97% soils of India are deficient in sulphur. This deficiency is becoming acute day by day due to extensive use of sulphur free fertilizers and intensive crop production**.** Production increases can be achieved by using improved varieties and adopting improved management practices. This review focuses on effect of sulphur on growth, yield, and quality of *Brassica spp"* (Jankowski *et al.*, 2008).

2. Effect of sulphur on the growth and development of *Brassica spp*

Sah *et al*. (2013) reported that plant height was significantly improved under 15 kg S/ha over control and remained unaffected with further increase up to 45 kg S/ha. Contrary to this, highest dose of sulphur 45 kg S/ha produced significantly higher counts of functional leaves and, branches as well as higher weights of dry matter per plant then the control. Maximum leaf area index (LAI) was produced with application of 30 kg S/ha which was significantly more than 15 kg S/ha and control. Begum *et al*. (2012) observed that significant increase in the mustard crop physiological parameters and seed yield. The 60 kg S/ha treatment produced the tallest plant, 104.5 and 102.8 cm, in both years of experimentation, while it was statistically at par with a treatment of 80 kg/ha in first year and significantly different from other treatments in second year. Sulphur generally tends to increase plant height. It enhances cell division, elongation, and expansion, but the application of sulphur beyond 60 kg/ ha did not influence plant height. Number of leaves per plant and leaf area index tended to increase with the application of sulphur up to 60 kg/ha at 58 days of emergence (DAE). Further increase in sulphur rate tended to depress number of leaves per plant possibly due to sulphur becoming unavailable to plants or might have created the toxic effect on mustard. This result is agreement with of results of Mohan and Sharma (1992), Nasreen *et al*. (2003), Dubey *et al*. (2017), Kumar *et al*. (2018), Verma *et al*. (2017). Kumar and Yadav (2007) reported that the effect of various levels of phosphorus and sulphur significantly influenced the growth attributes, viz. plant height and number of branches, leaf-area index and dry-matter accumulation. The plant height increased significantly with each increment in the dosage of phosphorus and sulphur up to 13.1 kg P and 15 kg S/ha. However, the differences in plant height due to further increase in the dose of P and S were not significant. The rate of increase in plant height was more at lower doses 13.1 kg P and 15 kg S/ ha. Application of 13.1 kg P/ha and 30 kg S/ha produced more number of primary branches at 90 days after sowing (DAS) compared with the control. However, application of 30 and 45 kg S/ha significantly increased the value of leaf-area index.

An increase in the level of P and S significantly improved the dry-matter accumulation. Variety 'NDR 8501' produced higher dry matter than 'Varuna'. Better nutrition to plants resulted in greater heights and numbers of branches, which resulted in higher dry-matter production. Bao-Luo Ma *et al*. (2015) reported that "developing efficient nutrient management regimes is a prerequisite for promoting canola (*Brassica napus* L.) as a viable cash crop in eastern Canada. Field experiments were conducted to investigate the growth, yield, and yield components of canola in response to various combinations of pre plant and sidedress nitrogen (N) with soil-applied sulfur (S) and soil and foliar-applied boron (B). Canola yield and all its yield components were strongly correlated (r 2 = 0.99) with the amount of N applied, as was the above-ground biomass at 20% flowering and the leaf area index. Sidedress N was more efficiently utilized by the crop, leading to greater yields than pre plant N application. On average, canola yields increased by 9.7 kg ha^{-1} for pre plant N application and by 13.7 kg ha^{-1} for sidedress N application, for every kg N ha^{-1} applied, in 6 of the 10 site-years. Soil-applied S also increased canola yields by 3–31% in 7 of the 10 site-years, but had no effect on yield components. While there was no change in yield from soil-applied B, the foliar B application at early flowering increased yields up to 10%, indicating that canola plants absorb B efficiently through their leaves. In summary, canola yields were improved by fertilization with N (8 of 10 site-years), S (7 of 10 site-years) and B (4 of 10 site-years). Yield gains were also noted with split N-fertilizer application that involved side dressing N between the rosette and early flowering stage. Following these fertilizer practices could improve the yield and quality of canola crop grown in rainfed humid regions similar to those in eastern Canada". Anjum *et al*.(2009) "field experiments were conducted at the farmer's field in Adhata village, Amdanga block, North 24 Parganas, West Bengal, India, during the dry season of 2005–2006 and 2006–2007 in an Inceptisol (pH 6.8) soil to evaluate nitrosulf and elemental sulphur treatments on the growth and yield of rapeseed (cv. B 9)". Four rates of nitrosulf and two rates of elemental S were applied to the soil. The total S content in dry matter of rapeseed gradually increased up to 80 days of crop growth when S was applied either as nitrosulf or elemental S, being greater with nitrosulf compared to elemental S application. The highest mean S uptake by rapeseed and straw was 286 and 190% increase over that of the control, respectively, in treatment of T_5 (0.2% S as nitrosulf). The mean plant height, number of siliqua plant^{-1}, number of seeds siliqua^{-1} and thousand seed weight were highest in treatment T_5 with 20, 34.8, 42.9 and 18.9% increase over that of the control, respectively. The yield of seed and stover recorded highest percentage increase of 66 and 71.6%, respectively, in the treatment T_5 over that of the control during both the years. F.C. OAD *et al*. (2001) "the field experiment was conducted at Sindh Agriculture University Tando Jam, Pakistan to determine the effect of row spacing on growth, yield and oil content of the rapeseed (*Brassica napus* L.). The homogeneous seed of P-53 rapeseed variety was given three row spacing *viz*. 30, 45 and 60 cm. The study envisaged that days to maturity, plant height, branches, pods, seed weight plant^{-1}, seed index, seed yield and oil content were affected significantly by row spacing. Among all, 60 cm row spacing proved to be best and is recommended for maximum seed and oil production".

Kumar *et al*. (2016) conducted "studies in Rabi season 2009-10 to evaluate 5 nitrogen rates and 2 zinc fertilizer rates on growth, yield and quality of Indian mustard. Application of 100 kg N/ha recorded significantly higher growth attributes viz., plant height (cm), number of total (primary + secondary) branches/plant, total dry matter accumulation at 60, 90 DAS and harvest stage, dry matter g/plant husk, stem as well as total and seed, straw as well as total. These applications also recorded significantly high yield attributes (no of siliquae per plant, length of siliquae per plant, number of seed per siliquae, seed weight per siliquae, 1000 seed weight, seed weight per plant) as well as grain yield (1804 kg/ha), biological yield (8406 kg/ha) and harvest index (21.6 %). In addition they, achieved high protein content and, protein and oil yield, although, maximum oil (42.3 %) content was recorded in a plot where N was absent. Moreover, like as above, application of 20 kg/ha zinc recorded maximum growth, yield and quality of Indian mustard over control plot. Thus, the combination of nitrogen @ 100 kg/ha and zinc @ 5 kg Zn/ha appeared to be more promising to boost the productivity of B. *juncea* on one hand and to improve its quality on the other".

3. Effect of sulphur on the yield of *Brassica spp*

Hasan *et al.* (2016) conducted "a study to evaluate five sulphur fertilizer formulations (ammonium sulfate, ammonium thiosulfate, gypsum, potassium sulfate, and elemental sulfur) applied in seed row at 20 kg S ha^{-1} alone, and in combination with 20 kg phosphorus pentoxide (P_2O_5) ha^{-1}, to three contrasting Saskatchewan soils. Wheat, canola, and pea were grown in each soil for 8 weeks and aboveground biomass yields determined. The fate of fertilizer was evaluated by measuring crop sulfur and phosphorus concentration and uptake, and supply rates and concentrations of available sulfate and phosphate in the seed row. Canola was most responsive in biomass yield to the sulfur fertilizers. Sulfate and thiosulfate were effective in enhancing soil-available sulfate supplies in the seed row, crop sulfur uptake, and yield compared to the elemental sulfur fertilizer. Combination of sulfur fertilizer with mono-ammonium phosphate may provide some enhancement of phosphate availability, but effects were often minor". Verma *et al.* (2012) reported that "the sulphur application of 60 kg S/ha gave significantly higher seed yield (20.98 q/ha) than control, 20 and 40 kg S/ha owing to better expression of siliqua length, number of siliquae/plant, number of seeds/siliqua, 1000-seed weight, harvest index and seed yield. Application of 60 kg S/ha recorded significantly higher seed yield and yield attributes than control". A similar result also was found by, Pradhan *et al.* (2020). Yadav *et al.* (2010) reported that the average seed yield was significantly affected by sulphur levels at mustard crop harvest. The yield increased progressively and significantly with each successive doses of sulphur. In S_0 level of sulphur, the seed yield was 16.83 as against 18.33, 19.33 and 18.87 q/ha recorded in S_{20}, S_{40} and S_{60} levels of sulphur, respectively. Dubey *et al.* (2009) conducted "an experiment at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Faizabad (Uttar Pradesh), during the *Rabi* season in RBD and replicated it three times". The treatments comprised four levels of sulphur (0, 20, 40 and 60 kg S ha^{-1}) and four levels of zinc (0, 5, 7.5 and 10 kg Zn ha^{-1}). The mustard variety "Varuna" was used as test crop. Application of 60 kg S ha^{-1} and 10 kg Zn ha^{-1}, produced significantly higher plant primary and secondary branches $plant^{-1}$, number of leaves $plant^{-1}$, days taken to flowering, days taken to maturity, number of siliqua $plant^{-1}$, length of siliqua, and number of seeds $siliqua^{-1}$, harvest index and oil content. However, dry matte accumulation $plant^{-1}$, 1000 -grain weight (g), biological yield, seed yield, stover yield and protein content significantly increased with increasing dose of sulphur up to 40 kg and zinc 7.5 kg ha^{-1}. The highest benefit cost ratio (1.68) was obtained with treatment combination $S_{40}Z_{7.5}$. The interaction effect of sulphur and zinc levels on various growth parameters of mustard was found non-significant.

Kumar and Yadav (2007) reported that the mustard crop seed and stover yields and oil content were significantly influenced by different phosphorus and sulphur levels. The highest seed yield and stover yield were recorded at 39.3 kg P/ha and 45 kg S/ha, which were on a par with those at 26.2 kg P/ha and 30 kg S/ha, and these were significantly superior to the control during both the experimental years. The increase in the seed yields due to application of 15, 30 and 45 kg S/ha over the control was 20.58, 42.3 and 48.0% during the first year and 22.0, 43.5 and 46.9% during the second year. Piri and Sharma (2006) reported that all the yield attributes, seeds/siliqua, 1,000-grain weight of Indian mustard increased significantly with increasing rates of sulphur up to 45 kg/ha however, the differences between 0 and 15 kg S/ha for siliquae/plant in both the years and 1,000-seed weight in second year, and between 15 and 30 kg S/ha for seeds/siliqua and 1,000 seed weight in both the years were not significant. Application of 45 kg S/ha recorded significantly higher straw yield than 30 kg S/ha which in turn gave significantly higher straw yield than the control. This was owing to a significant increase in plant height and branches/plant with increasing rate of sulphur application. Kumar *et al. (*2005) reported that application of 20 kg Fe/ha and 40 kg S/ha produced significantly higher seed and stover yields in comparison to control. The highest mean seed and stover yields of Indian mustard were recorded with the application of 20 kg Fe/ha, which were respectively 12.4 and 10.5% higher than of the control. Application of 40 kg S/ha recorded the highest seed and stover yields, which were respectively 28.1 and 37.4% higher than in the control. This increase might be attributed to the deficiency of these minerals in soil.

Rana *et al*. (2005) reported that favorable effects of P and S application on the mustard crop growth and yield attributes were further reflected by the seed yield, biological yield and harvest index. The seed and biological yields showed an increase with the application of phosphorus, but the effect between subsequent levels was significant only up to 25 kg P_2O_5/ha. The increase in seed yields with 25 and 50 kg P_2O_5/ha was 21.2 and 29.2%over the control, respectively. Sulphur application increased the seed and biological yields over subsequent level, but the margin between effects of 20 and 40 kg S/ha was not perceptible. The increase in seed yields at 20 and 40 kg S/ha over the control was 19.0 and 21.1%, respectively.

Rana and Rana (2003) observed "in a 2-year study that the maximum number of siliquae plant^{-1} (96.7 and 95.9) was observed at 60 kg/ha of sulphur (S_3) and the lowest number (60.5 and 59.7) was recorded from the control treatment in both the years. The number of siliquae per plant of mustard significantly increased up to 50 kg/ha which was also reported by Kumar *et al*. (2002). Maximum number of siliquae plant^{-1} (96.7 and 95.9) was observed at 60 kg/ ha of sulphur (S_3) and the lowest number (60.5 and 59.7) was recorded from the control treatment in both the years. The siliqua plant^{-1} of mustard significantly increased up to 50 kg/ha Kumar *et al.* (2002). The S fertilization at 80 kg/ha produced the highest number of seeds siliqua^{-1} (18.6), which was also at par with S_3 (60kg S/ha) and S_2 (40 kg S/ha) in this respect. The S_3 (60 kg S/ha) showed the highest seed yield per plant (18.91 g and 18.73 g). The S_3 showed 40.19% and 40.79 % higher seed yield than the control in both the years. Sulphur application significantly increased 1000-seed weight over S_0 level. Among S treatments, the highest 1000- seed weights (3.35 g and 3.37g) were shown by S_3 (60 kg S/ha), which was at par with S_4 (80 kg S/ha), and were 7.16 % and 5.64 % higher than that of control in both years, suggesting that the higher dosage favorably influenced the carbohydrate metabolism". This favorable effect led to increased translocation of photosynthetic products towards seeds resulting in formation of bold seeds. Kumar *et al*. (2016) conducted "experiments during Rabi seasons of 2009-10 and 2010-11 at Research Farm of Directorate of Rapeseed and Mustard Research (DRMR), Sewar, Bharatpur (Rajasthan), India". To achieve the objectives, different levels of sulphur a (0, 20, 40, 60 kg ha^{-1}) and nitrogen (0, 40, 80, 120 kg ha^{-1}) fertilization experiment were laid out in randomized complete block design consisting of three replications and data regarding various growth and yield parameters of Indian mustard were recorded using the standard procedures. The results revealed that the highest seed yield (2606.21 kg ha^{-1}) was obtained in the T_7 (60 kg ha^{-1} S and 120 kg ha^{-1} N) treatment followed by the T_6 (40 kg ha^{-1} S and 120 kg ha^{-1} N) treatment which gave 2588.91 kg ha^{-1} seed yield while minimum seed yield (1417.02 kg ha^{-1}) was recorded in control with no S and N. Glucosinolate content increased from 15.8 to 20.9 µ mol/g as S rate was increased from 0 to 40 kg ha^{-1}. Negi *et al*. (2017) conducted "an experiment at N.E. Borlaug Crop Research Centre, GBPUA&T, Pantnagar, in sandy loam soil during *Rabi* season of 2010 to evaluate effect of either zypmite or gypsum for sulphur on mustard crop. Treatments comprised of combinations of two sources (zypmite and gypsum) and three levels (20, 40 and 60 kg ha^{-1}) of sulphur along with a control (no sulphur) were replicated 3 times in a randomized block design. The plant height and dry weight were significantly affected by different treatments at 60 DAS. Significant increases in number of branches per plant, number of siliqua per plant, test seed weight and straw yield over control were recorded by 60 kg S ha^{-1} applied through zypmite. Grain yield showed numerical increase of 14.50% over control with 60 kg S ha^{-1} applied through zypmite".

4. Effect of sulphur on the quality of oil

Kumar and Yadav (2007) reported that 'Varuna' showed 7.4 and 4.94% higher oil content than 'NDR8501' during the first and second years, respectively. The increase in oil content with increase in S level might be due to the involvement of sulphur in electron-transport chain. Piri and Sharma (2006) reported that in mustard crop application of 45 kg S/ ha, being at par with 30 and 15 kg S/ha, significantly higher oil content was recorded in seed compared to the control. The increase in oil content with sulphur application might be because of sulphur role in oil synthesis, as S is a constituent of glutathione, a compound that plays a vital role in oil synthesis. Oil yield increased significantly with increasing level of sulphur up to 45 kg S/ha. Oil yield is a function of oil content and seed yield and both the parameters increased with increasing level of sulphur, thus resulting in a significant increase in oil yield. Kumar *et al*. (2005) reported that in mustard crop oil content increased significantly with the application of sulphur, which was lowest in the control (38.62%) and highest (40.82%) at 60 kg S/ha. The benefits may be attributable to the increase in glycosides. The oil production increased significantly with increase in S level. The maximum oil yield was observed in the treatment where 40 kg S/ha was applied. Similarly, application of Fe increased the oil yield from 6.20 q/ha in the control to 7.08 q/ha with 20 kg Fe/ha. Since oil yield is the resultant of seed yield and oil percentage, it also increased due to Fe and S because of increase in seed yield.

Nibedita Bose and Dilip Kumar Das (2009) "a field experiments was conducted at the farmer's field in Adhata village, Amdanga block, North 24 Parganas, West Bengal, India, during the dry season of 2005–2006 and 2006–2007 in an Inceptisols (pH 6.8) to evaluate the nitrosulf and elemental sulphur on the growth and yield of rapeseed (cv. B 9). Indeed, there are only four rates of nitrosulf and two rates of elemental S which were applied to the soil. The total S content in dry matter of rapeseed gradually increased up to 80 days of crop growth when S was applied either as nitrosulf or elemental S, being greater with nitrosulf compared to elemental S application. The highest mean S uptake by rapeseed and straw was 286 and 190% increase over that of the control, respectively, in the treatment T_5 (0.2% S as nitrosulf). The mean plant height, number of siliqua plant^{-1}, number of seeds siliqua^{-1} and thousand seed weight were highest in treatment T_5 with 20, 34.8, 42.9 and 18.9% increase over that of the control, respectively. The yield of seed and stover recorded highest percentage increase of 66 and 71.6%, respectively, in the treatment T_5 over that of the control during both the years".

5. Effect of sulphur on the nutritional quality of *Brassica spp*

Ram *et al.* (2011) "field experiment was conducted during *Rabi* season 2008 to study the effect of different levels of phosphorus and sulphur on availability of N, P, K, protein and oil content in Toriya (*Brescia* Sp.)Var.P.T.-303 on crop research farm Department of Soil Science and Agricultural Chemistry, Allahabad Agricultural Institute- Deemed University, Allahabad". Three levels of Phosphorus 0, 25, and 50 kg/ha, and three levels of Sulphur 0, 20, and 40 kg/ha were applied, respectively. During the course of experiment, observations were recorded as mean values of the data showed that there was significant increase in % nitrogen, % phosphorus, % potassium content in treatment combination T_5 (50.00 kg phosphorus + 40.00 kg sulphur/ha) and followed by T_4 (25.00 kg phosphorus + 20.00 kg sulphur/ha), respectively over than T_0 (Control). Kumar and Yadav (2007) reported that in the mustard crop increase in the levels of P and S increased the uptake of P. However, the differences were statistically significant only up to 26.2 kg P and 30 kg S /ha. Further increase in the dose of Po and S did not result in significant increase in P uptake by the crop. Uptake of S also increased with increase in the levels of P and S. Application of 26.2 kg P /ha significantly increased the S uptake over the control. Application of S also resulted in significant increase in the S uptake over the control only. Its application at 45 kg S /ha also showed significant S uptake over that of 15 kg S /ha. The increase in nutrient uptake was mainly due to better nutrition, which resulted in better growth and yield and ultimately in higher uptake of nutrients. Piri and Sharma (2006) reported that in mustard crop during 2003–04, S 30 kg /ha, being at par with 15 kg S /ha, significantly increased sulphur content in seed over no-sulphur(control), whereas in 2004–05 sulphur content increased with increasing rate of sulphur application up to 30 kg S /ha. Further increase in the rate of sulphur application from 30 to 45 kg S /ha did not increase sulphur content in seed further. Similar results were reported by Raut *et al.* (2000), Verma *et al*. (2018), Verma *et al*. (2020). Sulphur content in straw increased significantly with each successive increase in level of sulphur. Sources of sulphur, on the other hand, did not influence sulphur content of seed and straw. Sulphur uptake by Indian mustard ranged from 16 to31 kg /ha, of which 49–58% remained in seed and rest in straw. Further, increasing level of sulphur up to 45 kg /ha resulted in significantly higher sulphur uptake by both seed and straw over previous level. Rana *et al*. (2005) reported that on an average, Indian mustard removed more total sulphur than total phosphorus. There was a significant increase in the total P, S and B uptake owing to application of P and S. Phosphorus application increased the total uptake of P, S and B but the effect was significant only up to 25 kg P_2O_5/ha. With subsequent increase in P level from 0 to 50 kg /ha, the increase was 21.8 and 7.0% in P uptake, 10.1 and 5.5% in S uptake and 15.7 and 9.1% in B uptake. With the increase in S level from 0 to 40 kg S /ha, there was an improvement in the P, S and B uptake, but the margin between successive levels was significant only up to 20 kg S /ha.

6. Conclusion

From above the finding it may concluded that the application of sulphur significantly affected the growth, yield and quality of rapeseed. Application of 40 kg S ha^{-1} was found to be best treatments regarding growth, yield and quality of rapeseed. Thus, S nutrition in application of the rapeseed crop holds immense importance for obtaining better growth and productivity. Increasing S availability for rapeseed as to ensure the high protein content and better oil quality is important to address the health problem due to poor oil quality as well as content and malnutrition besides better crop production.

Reference

1. Ahmad G, Jan A, Arif M, Jan MT, Khattak RA. Influence of nitrogen and sulfur fertilization on quality of canola (Brassica napus L.) under rainfed conditions. *Journal of Zhejiang University. Science. B*. 2007; 8(10): 731–737.
2. Ahmed HP, Schoenau JJ, King T, Kar G. Effects of seed-placed sulfur fertilizers on canola, wheat, and pea yield; sulfur uptake; and soil sulfate concentrations over time in three prairie soils. *Journal of plant nutrition*. 2017; 40(4): 543-557.
3. Anjum NA, Umar S, Iqbal M, Khan NA. Carbon and nitrogen assimilation, and growth of moongbean (Vigna radiata [L.] Wilczek) cultivars grown under sulfur regimes. Archives of Agronomy and Soil Science. 2009; 55(2): 207-215.
4. Ankita N, Navneet P, Raverkar, Ramesh C. Effect Of Two Sulphur Sources On Growth, Yield And Nutrient Use Effeiciency Of Brassica International Journal of Science, Environment. 2017; 6(1): 236-247.
5. Begum F, Hossain F, Mondal MRI. Influence of sulphur on morpho-physiological and yield parameters of rapeseed (Brassica campestris L.). Bangladesh Journal of Agricultural Research. 2013; 37(4): 645-652.
6. Bose N, Naik SK, Das DK. Evaluation of nitrosulf and elemental sulphur on growth and yield of rapeseed (Brassica campestris L.) in India. *Archives of Agronomy and Soil Science*. 2009; *55*(1): 79-90.
7. Dubey D, Shukla RD, Pathak SVR. Yield and quality of wheat (Triticum aestivum L.) influenced by NPK levels, Sulphur levels and FYM. *IJCS*. 2017; *5*(6): 806-808.
8. Dubey S, Tripathi k, Singh B. Effect of Sulphur and Zinc Levels on Growth, Yield and quality of Mustard (Brassica juncea (L.) Czern and Coss.). A *Journal of Crop Science and Technology*. 2019; ISSN: 2319-3395

9. Egesel CO, Gul MK, Kahriman F. Changes in yield and seed quality traits in rapeseed genotypes by sulphur fertilization. *European Food Research and Technology*. 2009; 229(3): 505–513.
10. Jankowski K, Budzyński W, Szymanowski A. Effect of sulphur on the quality of winter rape seeds. *Journal of Entomology*. 2008; 13(4): 521–534.
11. Kumar A, Yadav DS. Long-Term Effects of Fertilizers on the Soil Fertility and Productivity of a Rice–Wheat System. *Journal of Agronomy and Crop science*. 2007; 186(1): 47-54.
12. Kumar R, Goyal V, Kuhad MS. Influence of fertility-salinity interactions on growth, water status and yield of Indian mustard (Brassica juncea). *Indian Journal of Plant Physiology*. 2005; 10(2): 139.
13. Kumar S, Patel A, Nath T, Verma S, Prajapati A. Response of sulphur and zinc nutrition on growth, yield attributes and yields of rapeseed (Brassica napus L.) under upland soil of Vindhyan region. *Journal of Pharmacognosy and Phytochemistry* 2018; 7(1): 135-140.
14. Kumar V, Kandpal BK, Dwivedi A, Sagar VK, Kumar V, Sharma DK. Effect Of Nitrogen And Zinc Fertilizer Rates On Growth, Yield And Quality Of Indian Mustard (Brassica Juncea L.) *International Journal of Agriculture Sciences*. 2016; 8(6): 1031-1035
15. Ma BL, Biswas DK, Herath AW, Whalen JK, Ruan SQ, Caldwell C, Smith DL. Growth, yield, and yield components of canola as affected by nitrogen, sulfur, and boron application. *Journal of Plant Nutrition and Soil Science*. 2015; *178*(4): 658-670.
16. Mohan K, Sharma HC. Effect of nitrogen and sulphur on growth, yield attributes, seed and oil yield of Indian mustard (Brassica juncea L.). Indian J Agron. 1992; 36(4): 748-754.
17. Nasreen S, Haq SI, Hossain MA. Sulphur effects on growth responses and yield of onion. *Asian Journal of Plant Sciences*. 2003; 2(12): 897-902.
18. Oad FC, Solangi BK, Samo MA, Lakho AA, Hassan Z, Oad NL. Growth, Yield and Relationship of Rapeseed (Brassica napus L.) under Different Row Spacing *International Journal Of Agriculture and Biology*. 2001; 3(4): 475-476.
19. Piri I, Sharma SN. Physiological analysis of growth and yield of Indian mustard as affected by irrigation and sulphur. *Indian Journal of Plant Physiology*. 2006; 11(3): 253.
20. Pradhan SS, Bohra JS, Pradhan S, Verma S. Effect of fertility level and cow urine application as basal and foliar spray on growth and nutrient uptake of Indian mustard (Brassica juncea). *Ecology environment and conservation*. 2017; *23*(3): 1549-1553.
21. Pradhan, S. S., & Verma, S. (2020). Effect of fertility levels and cow urine application as basal and foliar spray on quality and nutrient content of Indian mustard [Brassica juncea (L.) Czernj. & Cosson]. *IJCS*, *8*(2), 1216-1219.
22. Ram M, Davari MR, Sharma SN. Effect of organic manures and biofertilizers on basmati rice (Oryza sativa L.) under organic farming of rice-wheat cropping system. *International Journal of Agricultural Crop Science*. 2011; 3:76-84.

23. Rana K. Influence of phosphorus, sulphur and boron on growth and yield, nutrient uptake and economics of Indian mustard (Brassica juncea) under rainfed conditions. Indian journal of Agronomy. 2005; (50)4: 314-316.
24. Rana KS, Rana DS, Gautam RC. Influence of phosphorus, sulphur and boron on growth, yield, nutrient uptake and economics of Indian mustard (Brassica juncea) under rainfed conditions. *Indian Journal of Agronomy*. 2003; 50(4): 314-316.
25. Shah RA, Kumar, S. Direct and residual effect of integrated nutrient management and economics in hybrid rice wheat cropping system. *American-Eurasian Journal of Agriculture and Environment Sciense.* 2013; 14(5): 455-458.
26. Verma CK, Kedar P, Yadav DD. Studies on response of sulphur, zinc and boron level on yield, economics and nutrient uptake of mustard (Brassica juncea L.). *Crop Research (Hisar)*. 2012; 44(12): 75-78.
27. Verma S, Shori A, Kumar V, Verma SK, Singh JP. Response of kharif maize under different mulching and integrated nutrient management practices in eastern region of Uttar Pradesh. *IJCS*. 2020; *8*(2): 846-850.
28. Verma S, Singh A, Pradhan SS, Singh RK, Singh JP. Bio-efficacy of organic formulations on crop production-A review. *International Journal of Current Microbiology and Applied Sciences*. 2017; *6*(5): 648-665.
29. Verma S, Singh A, Pradhan, SS, Singh JP, Verma SK. Effects of organic formulations and synthetic fertilizer on the performance of pigeonpea in eastern region of Uttar Pradesh. *Bangladesh Journal of Botany*. 2018; *47*(3): 467-471.
30. Yadav HK, Thomas T, Khajuria V. Effect of different levels of sulphur and biofertilizer on the yield of Indian mustard (Brassica juncea L.) and soil properties. *Journal of Agricultural Physics*. 2010; 10(1): 61-64.
31. Walker KC, Booth EJ. Sulphur nutrition and oilseed quality. Sulphur in plants. 2003:323-39.