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AGRONOMIC RESPONSES OF MUSTARD TO FERTILITY LEVELS AND SULPHUR AVAILABILITY-A REVIEW

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Abstract: *India is one of the largest rapeseed-mustard growing countries in the world, occupying the first position in Area and second position in Production after China. The world production of Rapeseed/Mustard has been increasing at a rapid rate in several countries largely in response to the continuing increase in demand for edible oils and its products. Brassica (rapeseed-mustard) is the second most important edible oilseed crop in India and accounts for nearly 30% of the total oilseeds produced in the country. Mustard plantation is widely practiced in India, due to the ideal climate conditions and soil fertility present in this region. In addition, soil nutrition management is one of the most significant points in terms of crop production. Keeping in the view an attempt was made to review the work done on the effect of fertility doses and S level on yield and economics of mustard under irrigated condition as well as rainfed condition.*

Keywords: *Mustard, Growth, Yield, Economic, Sulphur and Fertility levels.*

Introduction: Mustard (*Brassica juncea*) is considered one of the most important oil seed crops which rank third in vegetable oils after soybean and palm while second in oilseed proteins production after soybean in the world. In India, the annual production of rapeseed-mustard was about 6.78 mt covering an area of about 5.92 mha with a total productivity of 11.45 qha^{-1} [1]. It is estimated that 58 mt of oilseeds will be required by the year 2020, wherein the share of rapeseed-mustard will be around 24.2 mt [2]. Of all the essential nutrients, nitrogen as an important limiting factor in crop productivity is required by the Mustard in its largest quantity. Plants usually obtain nitrogen by fertilizer application. Nitrogen supports the plant with rapid growth, increasing seed and fruit production and enhancing quality of leaf and oil seed crops [3]. Nitrogen management is crucial in cropping system; it is often difficult to strike between levels sufficient for normal plant growth and those that are acceptable for human consumption [4].

In addition of Nitrogen, application of potassium up to 60 kg ha^{-1} also significantly increased grain yields of Indian mustard. On an average, with the high potassium application of 80 kg ha^{-1}, 37.2% increase in grain yield was achieved as reported [5]. Seed yield and yield attributes of Indian mustard increased with increasing level of nitrogen and phosphorus up to 120 and 80 kg ha^{-1} respectively. Also reported in maize-mustard sequence, 100/75% of RDF + 2 t FYM gave highest seed yield and quality of the oil [6]. Significant increase in protein and oil content in mustard seed due to application of 150 kg N ha^{-1} compared to 50 kg N ha^{-1} [7]. Thus, adequate nutrient supply increases the seed and oil yields by improving the setting pattern of siliquae on branches, number of siliquae per plant and other yield attributes.

Effect of Fertility Levels on Growth Attributes: Conducted an experiment during on clay soils of Jabalpur (M.P.) [8] and found that plant height, leaf area index (LAI) and days to maturity increased significantly with higher fertility level i.e. 150% RDF (90:19.8:25 N:P:K kg ha^{-1}). Reported that significant improvement in number of leaf, primary branches and dry weight of cv [9]. Pusa Bold with application of 100 kg N+ 50 kg P ha^{-1} as compared to 60 kg N +30 kg P_2O_5 ha^{-1}and 80 kg N+40 kg P_2O_5 ha^{-1}.

Also rreported similar result from Allahabad [10]. Found that plant height increased significantly with the increasing fertility levels from 100 to 125% RDF [11]. While, not significant improvement in plant height recorded when fertility level increased from 100 to 125% RDF. The Leaf area plant^{-1} also increased significantly at 125% RDF. The application of 125% RDF (NPK) induced significantly higher growth characters during *rabi* season of Pantnagar. The maximum plant height, branches plant^{-1}, dry weight plant^{-1} were observed under 125% RDF, which were significantly higher over 50%, 75%, 100% RDF in Indian mustard reported [12] from Morena (M.P.). Revealed that application of 30 kg ha^{-1} P_2O_5 significantly increased LAI, PAR interception, whereas the effect of P application was non-significant on leaf chlorophyll content at PAU, Ludhiana [13]. Observed from their field study at Bharatpur and reported that the growth parameters improved with increasing dose of N up to 120 kg ha^{-1} and also found that higher production efficiency of the crop over 0, 40 and 80 kg N ha^{-1} [14]. Recorded the plant height and primary branches plant^{-1} increased significantly with increasing N doses up to 80 kg N ha^{-1} and for the secondary branches, dry matter plant^{-1} and leaf chlorophyll content up to 120 kg N ha^{-1} [15]. Moreover, the application of phosphorus up to 60 kg ha^{-1} too enhanced the dry matter plant^{-1} significantly during *rabi* season of Varanasi. Reported that the application of 100 kg N and 30 kg S, P 60 kg with blanket application of potash at 40 kg ha^{-1} recorded highest plant height, maximum plant dry weight and more number of siliqua plant^{-1} at Allahabad [10].

Effect of Fertility Levels on Yield Attributes and Yield: A field experiment was carried out in Jodhpur, Rajasthan and studied that application of 60 kg N ha^{-1} and 40 kg S ha^{-1} significantly improved yield and yield attributes. An increase of 38.45% was obtained with 60 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} over control revealed [16]. However, reported that nitrogen application significantly affected the seed yield and its attributes [17]. Application of 120 kg N ha^{-1} enhanced 8.16 and 46.59 per cent higher seed yield over 80 and 40 kg N ha^{-1}, respectively at Varanasi. Conducted the field experiment conducted at Jobner (Rajasthan) and revealed that application of up to 10 t FYM + 30 kg N and 20 kg P_2O_5 ha^{-1} significantly increased plant height, dry matter accumulation, number of primary and secondary branches per plant over the control (0 FYM + 0 N) [18]. Further, the response of potassium on yield of mustard crop, reported that with increasing potassium application rate, negative effect of water stress on grain yield was ameliorated and grain yield improved [19]. This might be due to potassium application can positively affect grain yield and water use efficiency of rapeseed and Indian mustard in severe and mild stress conditions. Also, it is concluded that potassium application was effective on plant growth and formation of economic yield by ameliorating damages caused due to water stress. Reported from Uttar Pradesh, that the plant height, number of functional leaves plant^{-1}, siliquae plant^{-1}, seed yield, total dry matter content ha^{-1} and stover yield linearly increase from 0 kg of P and S up to 60 kg P and 45 kg S ha^{-1} [20]. While, the results obtained under 15 kg S ha^{-1} was observed non-significantly higher than those traits by 30 kg S ha^{-1}. Reported that application of 100% RDF (80 kg N+40 kg P_2O_5) produced significantly higher seed yield (2372 kg ha^{-1}) [21] and other yield attributes viz. number of primary branches plant^{-1} (4.55), number of secondary branches plant^{-1} (9.40), number of siliquae plant^{-1} (195.35), seed weight (8.27 g plant^{-1}) test weight (4.63), stover yield (4771 kg ha^{-1}) of hybrid cultivar DMH^{-1} as compared to 75% RDF and found statistically at par with 125% & 150% RDF. While**,** observed that, the number of siliquae plant$^{-1,}$ weight of siliquae plant^{-1}, number of seeds siliqua^{-1} [8] and test weight of Rapeseed (*Brassica napus*) significantly increased with the increasing level of fertility up to 150% RDF. The seed and stalk yield also significantly increased with the increase in the level of fertilizers up to 150% RDF.

Observed from Allahabad and recorded more number of siliqua plant^{-1}, seed siliqua^{-1} [10] and the test weight with higher levels of 100 kg N, 30 kg S, 60 kg P_2O_5 and with blanket application of 40 kg K_2O ha^{-1} which ultimately resulted in higher seed yield over nitrogen (80 kg) sulphur (10 and 20 kg) and phosphorus (40 kg) ha^{-1}. Reported that seed yield increased with up to 100 kg N (1.66 t ha^{-1}) and 30 kg P_2O_5 (1.41 t ha^{-1}) [22]. Although, noted that P application up to 45 kg P_2O_5 ha^{-1} resulted significant increase in siliquae plant^{-1} [23]. Reported that number of siliqua plant^{-1}, number of seed siliqua^{-1} and seed yield increased significantly with the highest level of P (40 kg ha^{-1}) [18]. However, harvest index was not affected significantly by P application. Working with three rates of N and P combination *i.e*., 60 kg ha^{-1}+30 kg P_2O_5 ha^{-1}, 80

kg N+40 kg P_2O_5 ha^{-1} and 100 kg N+50 kg P_2O_5 ha^{-1} on the growth yield and quality of mustard (*B. juncea*) cv [9]. Pusa Gold and Kranti, resulted that higher fertilizer rates significant increase in number of siliqua $plant^{-1}$, length of siliqua and number of seed $siliqua^{-1}$, which consequently result in marked increase in harvest index and seed yield of both cultivars. Performed experiment at Jobner, Rajasthan, on mustard grown at loamy sand soil observed that application of phosphorus fertilizer at 60 kg ha^{-1} significantly increased the yield attributes and yield [24]. The highest number of siliqua $plant^{-1}$, seeds $siliqua^{-1}$ and seed yield were obtained with 60 kg P_2O_5 ha^{-1}. Studied the effect of varying fertility levels on mustard varieties (YTN-6,BSO-772, Vardan, JGN 01^{-1}5, Kranti and RH 9801) and found significantly higher yield with 100% RDF compared to 75 of recommended dose [25]. However, observed that the uptake of N increased significantly up to 80 kg N ha^{-1} [21]. Observed the mustard crop responded up to the highest level of the nitrogen (80 kg ha^{-1}) and recorded significant increase in siliquae $plant^{-1}$, seed yield, stalk yield and harvest index over control [26]. Result out that the increase in seed yield was significantly only up to 100% of the RDF [11]. The extent of increase in seed yield of toria (*Brassica compestris* var rapa) over 75% of RDF was 7.11, 9.20 and 10.84 %, due to application of 100%, 125% and 150% of RDF, respectively at Pantnagar. While, found that the combined application of 80 N+ 17.4P+ 33.3 Kg ha^{-1} synergistically increased the seed yield by 82.1% over 40 N+8.7 P kg ha^{-1} [27]. Supplementary use of balanced fertilizers (80 kg N: 17.4 kg P: 33.3 kg K) to either of organic treatments, synergistically improved the seed yield at least by three-fourth times from Bharatpur. Growth and yield attributes and maximum increment in seed and stalk yields of mustard were recorded with 80 kg N ha^{-1} and it were 8.54% and 14.26%, higher over the control, respectively. While, the application of N had increased significantly more number of grains $siliqua^{-1}$ up to 120 kg N ha^{-1} found from Muzaffarnagar. Moreover, the highest pods $plant^{-1}$, seed weight $plant^{-1}$and 1,000 seed weight were observed under 125% RDF, which were significantly higher over other doses [28]. The application of 125% RDF (NPK) induced significantly higher yield over other treatment and yielded 29.03%, 19.59% and 8.30% more seed yield over 50, 75 and 100% RDF respectively [12] on sandy loam soil at Morena (M.P.).

From Bharatpur, revealed that yield attributes improved with increasing dose of N up to 120 kg over 0, 40 and 80 Kg ha^{-1} [29]. The enhanced of yield under 120 kg N also resulted in higher production efficiency and WUE. Working during winter (*rabi*) season of Faizabad, consisted with 4 levels of P (0, 13.1, 26.1 and 39.3 kg ha^{-1}) and S (0, 15, 30 and 45 kg ha^{-1}), observed with significant up to 26.2 kg P in seed and stover yields [30]. Nutrient uptake was also highest under these treatments. The optimum dose of P was computed as 44.0 and 40.2 kg for the first and second years respectively. Reported that yield attributes of Indian mustard and lentil were recorded significantly higher with 50% and 100% RDF [31]. The maximum increment in seed yield of Indian mustard and lentil was recorded with 100% fertility level and it was 19.9 and 25.3% higher over the control respectively. Similarly, the application of 100% RDF to mustard improved the seed yield (1.31 t ha^{-1}) by 43.8 and 33.0% over control and 50% RDF also reported [29] from IARI, New Delhi.

Noticed that the seed and oil yield increased significantly up to 100% of RDF (N+P) and the increase was non-significant thereafter (125 and 150% RDF) [32]. The increase in seed and oil yield due to 100% over 75% of RF was 6.6% and 9% respectively. Yield $plant^{-1}$ and number of pod per main shoot (41.3) were found minimum at 75% of RF, whereas it was at par at other fertility levels. The number of seeds pod^{-1} was also less at 75% RF which increased significantly at 125 and 150% RF. The test weigh, height and siliqua length were not influenced by different fertility levels at Haryana. Reported that the application of 40 kg N + 20 kg P_20_5 ha^{-1} increased the seed yield significantly as compared to 20+10 kg NP ha^{-1} [33]. The significant increase in seed yield was observed with successive increase in fertility levels up to 60 kg N+30 kg P_20_5 ha^{-1} at CCSHAU, Hisar. Progressive increase in P and S levels increased yield attributes and seed yield of Indian mustard, but the increase in seed yield was significantly with 25 kg and 20 kg P_20_5 ha^{-1}. Seed yield response to tested levels of P and S was found quadratic on deep sandy loam soil of New Delhi [29]. Found that increasing level of nitrogen from 40 to 100 kg ha^{-1} significantly enhanced siliquae $plant^{-1}$, seed $siliqua^{-1}$, siliqua length, test weight, seed yield and NPK uptake of Indian mustard [34].

However, significant increase in stover and biological yields was recorded up to 120 kg N ha^{-1}. Identified the effect of irrigation and fertility levels on growth, yield, nutrient uptake, WUE, quality and economics of Indian mustard [*Brassica juncea* (L.) Czernj and Cosson] was carried out on sandy loam soil at Morena (M.P.) [20]. Among the fertility levels 125% (100N, 22 P, 20.7 K and 6.25 Zn kg ha^{-1}) RDF maintained significantly higher values of growth and yield contributory characters, production efficiency, nutrient uptake and quality components over 100% (80 N, 17.6 P, 16.6 K and 5.0 Zn kg ha^{-1}) RDF. Application of 125% RDF also achieved 19.94, 11.86 and 3.97% higher seed yield of mustard over 50, 75 and 100% RDF.

Effect of Fertility Levels on Grain Quality: Conducted a field trial at Varanasi, during *rabi* season and results revealed that oil content increased significantly with increasing fertility level up to 100% RDF (80:40:40:30 NPKS kg ha^{-1}) and there after decreased with increase in fertility [35]. However, protein content increased with increasing in fertility level and recorded the highest value at 150% RDF. The oil yield (kg ha^{-1}) increased significantly with the increasing fertility levels while oil content (%) had reverse trend for the same from Jobner, reported [18]. Protein content and protein yield (kg ha^{-1}) increased with the increasing fertility levels also reported [8] at Jabalpur. Oil content decreased significantly with each increment of fertilizer application beyond 75% of recommended dose. The decrease in oil content at 150% RF was 5.7% compared to 75% of RF also reported [32]. Conducted the field experiments at Kanpur (U.P.), evaluated that oil, glucosinolate and protein contents were higher at 60 kg P and S ha^{-1} and 30 kg Zn ha^{-1} over P (0 and 30 kg), S (0 and 30 kg) and Zn (0 and 15 kg) ha^{-1}, respectively [36]. On the contrary, oil constants, i.e. refractive index, iodine value and acid value, were significantly reduced by the application of P, S and Zn in both years. While, observed that the application of both P and S was beneficial in increasing seed and stover yield, oil content and oil yield, protein content, chlorophyll content and S-containing amino acids in seeds in Rajasthan [37]. Recorded decreased oil content with increasing N and P rates. Although the extent of decrease in seed oil content was lower than increase in seed yield and thus the total edible oil production was still higher with higher fertilizer rates compared to the normal recommended rates of fertilizer [9]. Evaluated that application of graded levels of potassium progressively improved yield attributes but in a decreasing order [38]. P uptake significantly increased up to 40 kg S ha^{-1}, thereafter, decreased significantly. Oil yield, oil quality and protein content also increased significantly with application of K. Percent utilization of added potassium was maximum when lowest potassium (0, 30, 60 kg) were applied at Kashmir. Reported that application of 125% RDF (NPK) induced significantly higher protein and oil yield over 50, 75 and 100% RDF, working at Morena [12]. Evaluated that highest protein and oil contents were obtained under S at 60 kg ha^{-1}. Quality parameters (protein content, oil content, protein and oil yield, P and S contents in seed and straw) were increased with increasing P levels, and were highest in 50 kg ha^{-1} [39]. Oil, glucosinolate and protein contents were higher at the application of 60 kg P and S ha^{-1} and 30 kg Zn ha^{-1}. On the contrary, oil constants, i.e. refractive index, iodine value and acid value, were significantly reduced by the application of P, S and Zn during the *rabi* season of Maharashtra.

Effect of Fertility Levels on Nutrient Uptake: Study revealed that the potassium application also increased the uptake of nitrogen, phosphorus, potassium and sulphur in mustard seed and straw; and also the oil and crude protein content in mustard seed in all the soils [40]. The significant effect was, however, observed up to 60 mg K kg^{-1} soil application. The chlorophyll content (both a and b) in mustard leaf, as measured at 45 days after sowing, also significantly increased with levels of potassium application at southern Haryana. The highest N, P and S contents in the seed (3.233, 0.795 and 0.297%) and in stover (0.528, 0.117 and 0.152%) and the highest uptake of N, P and S in the seed (46.95, 11.62 and 4.50 kg ha^{-1}) and stover (19.12, 4.47 and 5.40 kg ha^{-1}) were recorded upon treatment with 60 kg S ha^{-1}, observed [36]. In similar findings of above [41], also concluded that, the uptake of N, K and S at maturity was significantly affected with treatments. The P uptake significantly increased up to 40 kg S ha^{-1} and thereafter, decreased significantly. Percent utilization of added K and S was found maximum when lowest levels of K and S were applied. Oil, protein and total S-amino acid contents increased significantly with the application of S and K. Sulfur and K addition also significantly influenced the fatty acids composition; oleic and linoleic acid contents increased and erucic acid decreased showing

improved quality of mustard oil, from Kanpur, Uttar Pradesh. Revealed that increased N levels of up to 60 kg ha^{-1} significantly improved seed and oil yield as well as N and S uptake, whereas the protein yield showed significant improvement with N fertilizer application only up to 30 kg N ha^{-1} [42]. It was also observed that S application at 20 kg ha^{-1} significantly improved seed yield, oil yield, N and S uptake and protein yield compared to the control. Observed that seed yield and P uptake were higher in Indian mustard with application of 30 kg P ha^{-1} [38].

Recorded that higher oil, protein and seed yields aside from higher net returns and B: C ratio compared to Pusa Bold [43]. Increasing the nitrogen rate up to 80 kg ha^{-1} increased the crop quality aspects, N content and uptake, protein content, oil and protein yields and seed yield over 0 and 40 kg N ha^{-1}. However, oil content was negatively correlated with nitrogen rate. Reported that N and P uptake of Indian mustard and lentil increased significantly with the application of 50% and 100% RDF over control at IARI, New Delhi [31]. Result out that the uptake of NPK by both seed and stover increased significantly with successive increase in nitrogen levels up to 120 kg N ha^{-1} and sulphur levels up to 60 kg S ha^{-1} [15]. Noticed that owing to P and S levels, P, S and B uptake was significant only up to 25 kg P_20_5 and 20 kg S ha^{-1} on deep sandy loam soil of New Delhi [29].

Effect of Fertility Levels on Economics: A field experiment carried out during rabi 2009-10 and 2010-11 at Umedganj, Kota (Rajasthan) with consisting of four levels of recommended dose of fertilizer (NPK & S: 80, 40, 0 & 60 kg ha^{-1}) viz. 75%, 100%, 125% & 150% of RDF and four varieties of Indian mustard [Brassica juncea (L) Czern & Coss.] viz. DMH-1, NRCHB- 506, PAC-437 and Kranti (National Check). The higher net return (Rs.36776) and B: C ratio (2.62) found produced significantly with application of 100% RDF (80 kg N+40 kg P_2O_5) as compared to 75% RDF and found statistically at par with 125% & 150% RDF [21]. The result in support with the finding of [44] at Parbhani (MS) that the application of phosphorus significantly increased net return up to 80 kg P_2O_5 ha^{-1}. Reported that net profit of Rs. 4750 ha^{-1} was obtained under balanced use of 60 kg N ha^{-1}, 40 kg P_2 O_5 ha^{-1} and 15 kg S ha^{-1} [45]. Revealed that the application of 80 kg N ha^{-1} and 45 kg sulfur ha^{-1} significantly maximized net return ha^{-1} and benefit: cost ratio (Rs 13,148.5 and 2.41) and 45 kg S ha^{-1} (Rs 13, 171.1 and 2.38), respectively [21]. Reported that net monetary returns and B: C ratio increased with the increasing fertility levels up to 150% (90:19.8:25 N: P: K kg ha^{-1}) RDF during study [8]. Assessed the B: C ratio (2.55:1) was the highest in the cultivar PT synthetic-I at 125% of RDF followed by same cultivar at 100% of RDF level (2.54:1) from Pantnagar. Revealed from Kashmir, that application of 40 kg S ha^{-1} and 60 kg K_2O ha^{-1} besides improving quality and quantity of sarson, also registered high B: C ratio (1.54) [38]. While, Working at Morena reported that maximum net returns (Rs 31,275 ha^{-1}) and B:C ratio (3.25) were recorded in 125% RDF over 50, 75 and 100% RDF [12]. Achieved that the maximum net monitory returns of Rs. 40441 ha^{-1} and 36916 ha^{-1} and benefit cost ratio of 4.37 and 3.82 were realized under two irrigations and 125% (100N, 22 P, 20.7 K and 6.25 Zn kg ha^{-1}) RDF, respectively at Morena [20].

Effect of Sulphur Levels on Growth Attributes: Carried out an investigation with Indian mustard (*Brassica juncea* cv. 'RH 30') at Gurgaon, Haryana, revealed that increasing S levels significantly improved the growth attributes (plant height, primary branches per plant) and seed yield of Indian mustard [46]. Application of 45 kg S ha^{-1} produces significantly higher plant height, number of branches per plant and dry weight $plant^{-1}$ compared with the control reported [47] from Allahabad. Observed that the application of 60 kg N + 30 kg P_2O_5 + 20 kg S + 5 kg Zn ha^{-1} and 60 kg N + 30 kg P_2O_5 + 20 kg S ha^{-1} were superior in the enhancement of vegetative growth and yield of rai from Kanpur, Uttar Pradesh [48]. Revealed that increasing levels of nitrogen and sulfur appreciably improved the growth characters (plant height, branches $plant^{-1}$ and dry matter accumulation) at Varanasi [21]. Studied on the growth characters (Plant height and primary branches $plant^{-1}$) of Indian mustard (*Brassica juncea*) during *rabi* season of 1997-98 at Varanasi and revealed that all attributes increased significantly only up to 40 kg S ha^{-1} [15].

Effect of Sulphur Levels on Yield Attributes and Yield: Evaluated on the response of FYM and different sources and levels of sulphur on growth and yield at, Medziphema, Nagaland [22]. They revealed that yield attributes such as number of siliquae $plant^{-1}$, number of seed $siliquae^{-1}$, 1000 seed weight and seed and stover yield also increased significantly due to application of elemental sulphur. Conducted a field experiment at Ludhiana, Punjab, revealed

the yield attributes (siliquae per plant, seeds per siliquae and 1000-seed weight) and seed yields of Brassica species significantly increased by application of 25 kg S ha^1 [17]. However, the seed yields of Brassica species significantly increased with S application up to 50 kg ha^{-1}. Revealed from field experiment at Anand; that the maximum growth, yield attributes, and uptake of sulphur was found under 40 kg S ha^{-1} ultimately resulted in the highest seed yield of mustard, which was higher by 15.35% over control [49]. While, observed from Jodhpur, Rajasthan, and found that, application of 60 kg N ha^{-1} and 40 kg P_2 O_5 ha^{-1} along with 15 kg S ha^{-1} significantly improved yield and yield attributes [45]. Sulfur application at 15 kg ha^{-1} also significantly increased seed yield to the extent of 9.28%. Reported that, increase in seed yield with different treatments ranged from 8.9% with foliar application of thiourea at 0.05% at flower initiation to 22.2% with soil application of 20 kg S ha^{-1} as gypsum at sowing+foliar application of thiourea at 0.05% over the control [50]. Application of gypsum decreased the glucosinolate content in defatted seed meal. While, recorded highest yield and yield attributing characters of Indian mustard with application of 60 kg sulfur on sandy loam soil [51]. Work out on the study effect of 4 levels (0, 15, 30 and 45 kg S ha^{-1}) and 2 sources (gypsum and cosavet) of sulfur on yield attributes and yield of Indian mustard at New Delhi [27]. They revealed that, yield attributes, seed and straw yields increased significantly with increasing level of sulfur up to 45 kg S ha^1. Sulphur at 15, 30 and 45 kg ha^{-1} increased seed yield over the control by 9, 16 and 23%, respectively. Similar response in seed yield of Pro-Agro-4001 at 45 kg S ha^{-1} over 30, 15 and control by 3.4, 9.7 and 21.5%, respectively showed by [52] at Varanasi.

Showed that synergistic relationship of sulphur with potassium during conducted experiment at SKVAST Kashmir [38]. Application of graded levels of sulphur and potassium progressively improved yield attributes but in a decreasing order. The seed and stover yield increased linearly up to 40 kg S ha^{-1} and 60 kg K_2O ha^{-1}. Seed yield (2.03 t ha^{-1}) with 40 kg S was higher in comparison to control. However, a significant response of crop was also observed up to 30 kg S ha^{-1} in seed and stover yields [53] at Faizabad**.** But, progressive increase in P and S levels also increased yield attributes and seed yield, but the increase in seed yield was significantly only up to 25 kg P_20_5 and 20 kg ha^{-1} on deep sandy loam soil of New Delhi [29]. Revealed that application of Sulphur @40 kg ha^{-1} produced 19.3% higher seed yield than control during conducted a field experiment at New Delhi to comparative response of quality and traditional rapeseed-mustard genotypes of inorganic and organic source of nutrient [54].

Effect of Sulphur Levels on Grain Quality: A field experiment conducted with three levels of sulphur (0, 20 and 40 kg ha^{-1}) and calcium (0, 10 and 20 kg ha^{-1}) to study the yield and quality of mustard [Brassica juncea (L.) Czern & Coss.] cv. Varuna as test crop. Revealed that application of sulphur (S) and calcium (Ca) alone and in combination significantly affected the siliqua, yield, oil content and quality of oil [53]. In each case, the application of S at 40 kg ha^{-1}+Ca at 10 kg ha^{-1} was found superior over other treatments. However, the application of Ca at 20 kg ha^{-1} with S adversely affected the siliqua number, yield, oil content and quality of oil. However, the sulphur applied at rate of 60 kg ha^{-1}, produced significantly higher oil and protein content as well as oil yield over 30 kg S ha^{-1} reported on Indian mustard var. PRO-4001 [17]. Recorded 45 kg S ha^{-1} highest in the oil content (41.84%) and oil yield (0.63 t ha^{-1}) [55]. The highest dry matter production and S uptake were for 15 and 30 kg S ha^{-1} during studied at Pusa, Bihar. While**,** Application of 15, 30 and 45 kg S ha^{-1} increased the oil yield over the control by 13, 22 and 33% , respectively [27]. Observed that the seed and straw yield increased significantly with increase in levels of S [56]. While, the test weight and protein content were significantly increased with the increasing levels of S and Zn. The oil content increase with increasing levels of S and Zn, but increase was no significant on loamy sand (Typic Ustochrepts) at Gujarat. Evaluated that oil yield, oil quality and protein content increased significantly with application of S (0, 20, 40 and 60 Kg ha^{-1}) and K (0, 30, 60, 90 kg ha^{-1}) [57]. Percent utilization of added sulphur and potassium was found maximum when lowest sulphur and potassium were applied on brown sarson at Kashmir.

Effect of Sulphur Levels on Nutrient Uptake: Results showed that growth attributes increased significantly only up to 40 kg S ha^{-1} and the uptake of S by both seed and stover increased significantly with successive increase in sulphur levels up to 60 kg S ha^{-1} at Varanasi [15]. Similar result also reported [58]. However, the highest dry matter production and S uptake were for 15 and 30 kg S ha reported by [55] at Pusa. The maximum

S uptake (34.5 kg ha) uptake was recorded with 45 Kg S per hectare, respectively also reported [56, 52]. Studied on the response of sulphur application on growth, yield attributes and yield of mustard under middle Gujarat condition, and revealed that the maximum growth, yield attributes, and uptake of sulphur under 40 kg S ha^{-1} ultimately resulted in the highest seed yield of mustard, which was higher by 15.35% over control [49]. Found from New Delhi, revealed that the sulfur content and uptake in seed and straw increased significantly with increasing level of sulfur up to 45 kg S ha^{-1}. S at 15, 30 and 45 kg ha^{-1} increased seed yield over the control by 9, 16 and 23%; oil yield by 13, 22 and 33%; and sulfur uptake by 25, 48 and 65%, respectively [27]. Evaluated on the response of FYM and different sources and levels of sulphur on growth and yield at, Medziphema, Nagaland and results revealed that the sulphur doses increased, total uptake and available nutrient content also increased significantly [22].

Showed synergistic relationship of sulphur with potassium [41]. The uptake of N, K and S at maturity was significantly affected with treatments i.e. S (0, 20, 40 and 60 kg S ha^{-1}) and potassium (0, 30, 60 and 90 kg K_2O ha^{-1}) on Udic Haplustepts of Kanpur. The P uptake significantly increased up to 40 kg S ha^{-1} and thereafter, decreased significantly. Percent utilization of added K and S was highest; when, lowest levels of K and S were applied. Oil, protein and total S-amino acid contents increased significantly with the application of S and K. While, the highest P and S contents in straw and seed, and uptake were also obtained under sulphur at 60 kg ha^{-1} in Maharashtra [39]. Similar, result also revealed [35]. While, reported that the application of 40 kg S ha^{-1} applied through either gypsum or elemental S were found equally effective in their effect but recorded significantly higher uptake of S by seed and N by seed and stover compared to the control and lower level of S applied either through gypsum or elemental S during conducted experiment at Gujarat in the winter season [59], from Varanasi, studied the growth and nutrient uptake pattern of Indian mustard (*Brassica juncea*) at various levels of N, P and S. Plant height and primary branches $plant^{-1}$ increased significantly up to 80 kg N ha^{-1} and secondary branches, dry matter $plant^{-1}$ and leaf chlorophyll content up to 120 kg N ha^{-1} [15]. Application of phosphorus up to 60 kg ha^{-1} significantly enhanced dry matter $plant^{-1}$. Whereas plant height, branches $plant^{-1}$ and leaf chlorophyll content increased significantly only up to 40 kg P_2O_5 ha^{-1}. All growth attributes increased significantly only up to 40 kg S ha^{-1}. The results showed that the uptake of NPK and S by both seed and stover increased significantly with successive increase in nitrogen levels up to 120 kg N ha^{-1} and sulphur levels up to 60 kg S ha^{-1}.

Revealed that Indian mustard removed more S and P. Owing to P and S levels, P and S uptake was significant only up to 25 kg P_20_5 and 20 kg S ha^{-1} [29]. The seed yield response to tested levels of P and S was found quadratic on deep sandy loam soil of New Delhi. Observed that sulphur content and uptake in both seed and stover increased significantly with increasing level of sulphur up to highest level of 45 kg S ha^{-1} [27]. Application of 15, 30 and 45 kg S ha^{-1} increased the sulphur uptake yield over the control by 25, 48 and 65% respectively. Studied the response of Indian mustard cv. T-59 to nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and sulfur (0, 20, 40 and 60 kg ha^{-1}) rates in Bikaner, Rajasthan [5]. Nitrogen and sulfur content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N ha^{-1} over its preceding rates. The increased nitrogen and sulfur content enhanced the total uptake of nitrogen and sulfur. Sulfur fertilizer application at 20 kg ha^{-1} increased oil content in mustard over the control. Oil yield and chlorophyll content were enhanced up to 40 kg S ha^{-1}.

Effect of Sulphur Levels on Economics: Observed during the field experiment conducted at Kanpur, and revealed that application of 60 kg S ha^{-1} gave significantly higher seed yield and nutrients uptake (kg ha^{-1}) than control, 20 and 40 kg S ha^{-1} during experimental years [35]. On economic basis, the highest profit was recorded with combined use of 60 kg S ha^{-1}+5 kg Zn ha^{-1} and 1.0 kg B ha^{-1}. Found from conducted experiment at Jodhpur, that, application of 60 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} along with 15 kg S ha^{-1} significantly improved net profit of Rs. 4750 ha^{-1} was obtained under balanced use of 60 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 15 kg S ha^{-1} [45]. Revealed that the net returns and benefit: cost ratio were higher with basal application of 20 kg S ha^{-1} through gypsum+foliar application of thiourea (0.05%), closely followed by spray of 0.15% sulfuric acid and soil application of gypsum to supply 40 kg S ha^{-1} [51].

Revealed that application of 40 kg S ha^{-1} and 60 kg K_2O ha^{-1} besides improving quality and quantity of sarson, also registered high B: C

ratio (1.54) [57]. While, the maximum net return 30940 was obtained with fertilizer application of 120 kg N ha^{-1} +20 kg S ha^{-1} which gave the cost benefit ratio of 1:2.58 against net return of only 9340 Rs ha^{-1} with 1: 1.02 cost benefit ratio under control [28]. Recorded highest net returns of Rs. 13,734 ha^{-1} with the application of 45 kg ha^{-1} S over control [30] and 30 kg S ha^{-1} at Faizabad. Similar result also reported [29].

Conducted a field experiment at Varanasi, and observed that maximum net return ha^{-1} and benefit: cost ratio was observed with 80 kg N ha^{-1} (Rs 13,148.5 and 2.41) and 45 kg S ha^{-1} (Rs 13, 171.1 and 2.38) [21].

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