CHAPTER-II
REVIEW OF LITERATURE

The productivity of any crop is a complex phenomenon which is governed by numerous endogenous and exogenous factors. It can be enhanced by adopting suitable agro-techniques viz., use of improved varieties, timely sowing, appropriate spacing, fertilizer management, proper irrigation scheduling and proper measures to minimize losses through weeds, insect-pests and diseases. Among various agronomical factors responsible for increasing productivity of any crop, fertilizer management play important role for harvesting potential production of Indian mustard under different agro-climatic conditions.

An attempt has been made to review the available literatures concerning the present investigation are presented in this chapter. The work done, especially on these aspect of mustard is very meagre; hence similar work on other crops has also been included whenever felt necessary. A brief summary on research work done in the past by eminent scientists in India and abroad on related aspects has been highlighted and reviewed under the following broad topics.

2.1 Effect of potassium
2.2 Effect of sulphur
2.3 Interaction effect of potassium and sulphur

2.1 EFFECT OF POTASSIUM

Potassium plays an important role in the maintenance of cellular organization by regulating the permeability of cellular membranes. K imparts increased vigour and disease resistance to plants. It maintains the balance between respiration and transpiration. K deficient plants show a reduced rate of photosynthesis and mottled chlorosis.

Ghosh et al. (1995) recorded a response of 3.73 kg mustard seeds per kg of K₂O added irrespective of the status of K in the soils.

Dixit and Gautam (1996) stated that total uptake of N, P, K were highest in mustard crop receiving the recommended dose of fertilizer i.e., 80-40-40 kg N, P₂O₅, K₂O/ha.

Tomer et al. (1996) noticed that plant height, number of branches, dry-matter accumulation/plant, number of silique/plant, 1000-seed weight, seed and oil yields/ha
increased significantly with the increasing levels of fertilization up to 120 kg N + 60 kg P₂O₅ + 60 kg K₂O/ha in Indian mustard.

Badiyala and Kumar (2003) conducted an experiment on linseed at Palampur and observed that application of 50 kg N + 40 kg P₂O₅ + 20 kg K₂O/ha significantly increased plant height and number of primary branches per plant over lower levels.

Misra (2003) showed that seed and stover yields of Indian mustard responded significantly to the application of 60 kg K₂O/ha. Application of 60 kg K₂O/ha produced highest seed yield (2085 kg/ha) which was 35.5% higher in comparison to the yield in control. The uptake of N and K at maturity was significantly affected with treatments.

Tahir et al. (2003) reported that different levels of N, P and K significantly influenced the yield components such as number of siliqua/plant, number of seeds/siliqua and 1000-seed weight of Indian mustard. They observed highest seed yield and net income with the application of NPK @ 100-60-50 kg/ha as compared to other levels of NPK.

Khan et al. (2004) revealed that the highest seed yield (3473 kg/ha) was obtained with K @ 150 kg/ha, which was however, at par with treatments where 50, 75, 100 and 125 kg K/ha was applied. While minimum seed yield (2585 kg/ha) was recorded in case of control i.e., with no K. Oil content progressively decreased with increase of K level with highest (42.86%) in case of control and lowest (37.42%) with a K level of 150 kg/ha. But a perusal of economic analysis showed that application of 125 kg K/ha in Indian mustard was more economical than all other treatments.

Mandal and Sinha (2004) reported that number of siliqua/plant, seeds/siliqua, 1000-seed weight and seed yield of Indian mustard improved significantly with 100% recommended dose of NPK @ 80-17.2-33.2 kg/ha along with FYM @ 10 t/ha.

Pandey and Bharati (2005) observed that both the levels of potassium (30 and 60 kg/ha) recorded significantly higher values of yield attributes viz., number of primary and secondary branches, siliqua/plant, seeds/siliqua, 1000-seed weight, seed yield, stover yield, oil yield and N, P, K uptake by the mustard crop over the control. Oil content in grains not significantly influenced by levels of K.

Tomar and Tiwari (2005) conducted a field experiment on Indian mustard cultivars (CS-614-41-4, SAL-7, Kranti, SAL-9 and CS-52) to N, P, K at 60-30-15, 80-40-20, 100-50-25 and 120-60-30 kg/ha. SAL-9 showed higher yields than the other cultivars.
Increasing N, P, K rates up to 100, 50, 25 kg/ha produced higher seed, stover and biological yield over rest of the treatments.

In a sand culture experiment on mustard cv. Varuna, application of 20 mM K enhanced yield characteristics like number of silique/plant by 138.6 %, seeds/silique by 9.4 %, 100-seed mass by 2.0 %, seed yield/plant by 200.0 % and oil content by 8.3 % over the minimum level of K, i.e., 5 mM K (Mohammad and Naseem, 2006).

Karwasara and Kumar (2007) found that application of 20, 40 and 60 kg K₂O/ha increased seed yield of mustard by 9.42, 10.20 and 10.70 q/ha over the control.

An experiment was conducted by Fanaei et al. (2009) on Indian mustard at Zabol (Iran) and reported that fertilization of 250 kg K₂O/ha increased seed yield (2975 kg/ha) and water use efficiency by 52% and 22% over control in mild water stress conditions, respectively.

Gavade and Shigvan (2009) revealed that the application of potassium @ 60 kg/ha to Indian mustard increased seed yield from 2.21 to 9.15 q/ha, whereas potassium elevated to 5.69 and 5.00 q/ha, respectively. Potassium @ 60 kg/ha showed the maximum ability to generate the free proline content under water stress condition.

The response of mustard crop to potassium application was studied by Grewal et al. (2009). Application of potassium, in general, increased the seed yield, stover yield, the uptake of nitrogen, phosphorus, potassium and sulphur by mustard seed and stover; and also the oil and crude protein content in mustard seed in all the soils. The response was, however, significant up to 60 mg K/kg soil.

Vivek et al. (2009) conducted a field experiment on mustard at Crop Research Center, Modipuram, Meerut (UP) and reported that silique/plant, seeds/silique, 1000-seed weight and yield of mustard increased by application of 125% NPK over 75% NPK.

Athopam et al. (2010) conducted a field trial taking 13 treatment combinations consisting of three doses of nitrogen (50, 100 and 150 kg), two levels of phosphorus (50 and 100 kg), two levels of potassium (50 and 100 kg/ha) and a control for each treatment, replicated thrice in Indian mustard. The result revealed that leaf area index, net assimilation rate, plant growth efficiency, dry matter percentage increased significantly in highest fertility levels of 100 kg N/ha, 100 kg, P₂O₅/ha, and 100 kg K₂O/ha in comparison to control.
Lone et al. (2010) studied the effect of different combinations of phosphorus and potassium (each @ 30, 60, 90 kg P<sub>2</sub>O<sub>5</sub>/K<sub>2</sub>O/ha) on yield and yield attributes in Indian mustard. Various yield characteristics viz., number of siliquae/plant, number of seeds/siliqua, seed yield and oil yield were assessed with the application of 60 kg P<sub>2</sub>O<sub>5</sub>/ha and 60 kg P<sub>2</sub>O<sub>5</sub> + 60 kg K<sub>2</sub>O/ha.

Mir et al. (2010) found that fertilization with 60 kg P<sub>2</sub>O<sub>5</sub>/ha and 60 kg P<sub>2</sub>O<sub>5</sub> + 60 kg K<sub>2</sub>O/ha to Indian mustard increased number of siliquae/plant, number of seeds/siliqua, seed yield and oil yield.

Singh et al. (2010c) studied the effect of different levels of N and P and K on Indian mustard cv. Varuna and found that increasing levels of N up to 120 kg/ha, K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> up to 45 kg/ha increased the length of siliqua, number of siliqua, seed/siliqua, seed yield and test weight significantly.

Yadav et al. (2010b) stated that the application of 125% recommended dose of NPK fertilizers (RDF) to Indian mustard induced significantly higher growth and yield characters, water use efficiency, protein and oil yield over other treatments and yielded 29.0%, 19.6% and 8.30% more seed yield over 50, 75 and 100% RDF, respectively.

An field experiment was conducted on cotton black soil at Nagpur to investigate the effect of various levels of NPK on the plant height, number of branches and on the seed yield of mustard. From the results of the experiment, Dalal and Nandkar (2011) revealed that maximum number of branches/plant, plant height, number of pod/plant and seed yield were recorded with the application of 50 : 40 : 25 kg NPK/ha.

Ghimire and Bana (2011) evaluated that oil yield (340 and 627 kg/ha), protein yields (245 and 456 kg/ha), glucosinolate content (80.3 and 87.6 mM/g of seed) and protein content (23.7 and 22.9%) improved significantly upto 100% of RDF in 2008-09 and 2009-10, respectively. A density of 1000 trees/ha and 100% RDF (120 kg N + 17.4 kg P<sub>2</sub>O<sub>5</sub> + 16.6 kg K<sub>2</sub>O/ha) was found most suitable and economical for mustard-poplar mixed agrisilvicultural system.

Gupta et al. (2011) showed that higher dose of nitrogen (120 kg N/ha) produced maximum oil yield. Split application (50% basal + 50% at 1st irrigation) of potassium also produced higher protein content (22.78%) and oil content (39.34%) than basal dose of potassium in Indian mustard.
Cheema et al. (2012) concluded that potassium application @ 120 kg/ha increased leaf area index, crop growth rate, seed yield (3067 kg/ha) and oil quality of canola.

Mozaffari et al. (2012) evaluated that 90 kg K$_2$O and 150 kg N/ha is best and more economical than all other treatments for achieving the highest traits of 1000-seed weight, seed yield, seed oil yield and harvest index and the treatments 75 kg N and 90 kg K$_2$O/ha for the highest trait of seed oil content in Indian mustard.

Tiwari et al. (2012) investigated that increasing doses of potassium up to 60 kg K$_2$O/ha significantly increased seed and stover yields of mustard crop from 1645 to 2257 kg/ha and 4041 to 5077 kg/ha, respectively. The highest oil content (41%) was obtained at 60 kg K$_2$O/ha which was about 16 per cent higher than the control. K content and removal of K from the soil by mustard crop progressively increased from 0.88 to 0.99% and 143 to 184 kg K$_2$O/ha, respectively between the 0 to 80 kg K$_2$O/ha levels. On an average, with the high potassium application of 80 kg/ha, 37.2% increase in seed yield was achieved. Likewise, protein and oil content were also increased significantly by K application. Similar results showing the benefit of K on crop yield have also been reported by Prasad and Shukla (1993).

Meena et al. (2013) revealed that the maximum positive effect was observed with 150% RDF on number of primary branches/plant (4.55), number of secondary branches/plant (9.40), number of siliquae/plant (195.35), seed weight (8.27 g/plant), test weight (4.63), seed yield (2157 kg/ha), stover yield (4771 kg/ha), oil content (41.30%), oil yield (933 kg/ha), net return (₹ 36776) and B : C ratio (2.62) as compared to 125 %, 100 % and 75 % for all the characters in Indian mustard.

Yadav et al. (2013) found that application of 60 kg K$_2$O/ha significantly increased mustard seed yield by 14.6% and straw yield by 13.4% over control. The oil content, protein content, K content and K uptake by mustard crop increased with potassium fertilizer application up to 60 kg/ha to the soil.

Bhati et al. (2014) reported that application of potassium @ 60 kg K$_2$O/ha significantly increased number of siliquae/plant, number of seeds/siliqua, length of siliqua and 1000-seed weight by 48 and 16.8 per cent; 44.2 and 18.5 per cent; 43.8 and 16.4 per cent and by 46.4 and 18.4 per cent over control and 20 kg K$_2$O/ha, respectively. However, the effect of 80 kg K$_2$O/ha was found to be at par with 60 kg K$_2$O/ha on all these yield attributing characters.
**Review of literature**

Mandal and Chattopadhyay (2014) observed that the treatment receiving 140 kg N, 175 kg P$_2$O$_5$, and 112 kg K$_2$O appeared to be the most effective in improving various growth attributes, yield attributes and highest seed yield (1.65 t/ha) of mustard.

Paliwal and Singh (2014) observed that number of silique/plant (324.5), length of silique (4 cm), seed yield (1817 kg/ha), 1000-seed weight (3.7 g), seed weight/plant (13.9 g), protein yield (306 kg/ha) and oil yield (736 kg/ha) of Indian mustard was recorded maximum at 150% (120: 60: 40 kg N, P$_2$O$_5$ and K$_2$O/ha) NPK level under tarai condition of Uttarakhand.

Gajghane *et al.* (2015) observed that the maximum available N (317.2 kg/ha) and available P (18.9 kg/ha) were recorded with the application of 45 kg K$_2$O/ha, followed by the treatment 30 kg K$_2$O/ha and the lowest available N was recorded in control (308.4 kg/ha).

Tikkoo *et al.* (2015) found that mustard responded to K application up to 20 kg K$_2$O/ha. The potash application significantly increased crop yield, K concentration and K uptake.

The field experiment was laid down during rabi season 2012 at research farm of Baghpat (UP) on loam soil. Tomar (2015) concluded that 100% of the recommended fertilizer dose (N$_{80}$ + P$_{40}$ + K$_{40}$) + two irrigation (at 30 DAS and flowering stage) and hand weeding at 30 DAS are the recommended for mustard crop because they increased seed yield, stover yield than other management practices and pendimethalin 1.0 kg/ha.

Meena *et al.* (2016) noticed that application of 80 kg N/ha, 40 kg P$_2$O$_5$ and 30 kg K$_2$O/ha registered significantly higher branches/plant, silique/plant, seeds/silique, test weight and seed yield of mustard over lowest levels of these nutrients.

Kumar *et al.* (2016a) concluded that Indian mustard cultivar RGN-73 fertilized with 100 kg N, 40 kg P$_2$O$_5$ and 30 kg K$_2$O/ha sustained higher seed, stover and biological yields, and net returns under tarai condition of Uttarakhand.

An experiment were conducted during the winter season of 2014-15 and 2015-16 at Bikaner. Bijarnia (2017) observed that the growth parameters *viz*., plant height, dry matter accumulation and leaf chlorophyll and yield parameters like number of silique/plant and seeds/silique which lead to the highest seed and straw yield under the treatment 5 t FYM + 100 % RDF.
2.2 EFFECT OF SULPHUR

Sulphur plays an important role in plant metabolism. It is part of the amino acids, methionine and cysteine and participates in the synthesis of many secondary compounds in the plant. The supply of sulphur, therefore, influences oil content, protein content, protein composition of chlorophyll and glycosides. Consequently, the supply of sulphur to the plant has a decisive effect on the quality of the crops (Schnug, 1998).

Chauhan et al. (1996) found that yield attributes like seeds/siliqua, 1000-seed weight of mustard increased significantly with increasing rates of sulphur up to 45 kg/ha.

Dhankar et al. (1996) observed that an increasing level of sulphur in mustard significantly increased plant height, primary and secondary branches and seed yield up to 60 kg S/ha.

Tomar et al. (1997) studied that the growth attributes (plant height, branches/plant, and dry-matter accumulation/plant) and yield attributes (pods/plant, seeds/pod and 1000-seed weight and stover yield/ha) increased significantly with the increasing levels of N, P and S up to 180, 80 and 80 kg/ha, respectively. The oil content of seed increased with increasing levels of S.

Among oil seed crops, rape seed and mustard have highest requirement of S with the optimum level ranging from 20 to 60 kg S/ha (Aulakh and Pasricha, 1997). Similarly, Tiwari et al. (2003a) also reported that significantly higher yield of mustard was obtained at farmers field by using sulphur at different doses viz., 20, 30 and 40 kg S/ha.

Bansal et al. (2000) found that the application of ammonium sulphate (40 kg/ha) in mustard had significant effect on growth, yield, yield components, protein and oil content and total sulphur uptake.

Bhagat and Soni (2000) found that application of sulphur up to 50 kg/ha significantly increased oil content and oil yield in mustard.

Ghosh et al. (2000) noticed that the increase in the seed yield of Indian mustard due to application of 45 kg S/ha over the control was 48.0% during the first year and 46.9% during the second year, whereas the increase in oil content due to 45 kg S/ha over the control was 11.53% and 9.02% during 2000-01 and 2001-02, respectively.

Mehriya and Khangarot (2000) reported that application of 150 kg S/ha significantly increased the plant height, dry matter accumulation and number of
branches/plant, the test-weight, seed and straw yield, and oil content over control. Application of sulphur resulted in increasing availability of sulphur and also increased the availability of applied nitrogen and phosphorus.

Singh and Nad (2000) reported that yield of mustard increased significantly when 60 kg S/ha was applied along with N @ 120 kg/ha.

Kumar et al. (2001a) evaluated that plant height, primary and secondary branches per plant, number of siliquae/plant, seeds/siliqua, 1000-seed weight, protein content, oil contents and harvest index were obtained with the application of 40 kg S/ha as compared to the control and 20 kg S/ha.

Kumar et al. (2001b) reported that the highest seeds/plant, seeds/siliqua and 1000-seed weight were obtained with 25 kg S/ha which was significantly higher over the control in Indian mustard.

Chandel et al. (2002) revealed that increasing sulphur levels up to 40 kg/ha significantly improved leaf area index, dry matter production, harvest index and sulphur content in Indian mustard.

Chauhan et al. (2002) stated that oil content of mustard seed was significantly increased up to 30 kg S/ha.

Kumar et al. (2002) revealed that the number of seeds/siliquae and 1000-seed weight of mustard was significantly increased with the application of 40 kg S/ha.

Prakash and Singh (2002) stated that highest number of branches/plant was observed with increase in sulphur rate up to 40 kg/ha.

Gypsum application (250 kg/ha) reflected in significant improvement in yield attributes and seed yield of Indian mustard (Brassica juncea L.) (Rao and Shaktawat, 2002).

Singh et al. (2002) studied the effect of different fertility levels on yield attributes, seed yield, harvest index, oil content and oil yield of promising Brassica varieties. Number of branches/plant (31.86), seed weight/plant (4.75), 1000-seed weight (4.4g), seeds/siliqua (9.7) and seed yield (1,350 kg/ha) were highest in ‘PCB-9221’ (Kiran) of Brassica carinata.

Sudhkar et al. (2002) reported that application of sulphur @ 60 kg/ha significantly improved plant height and primary and secondary branches over the lower doses of sulphur.
Abdin et al. (2003) observed that the protein content in the seed of mustard can be optimized with the split application of 40 kg S/ha during the appropriate phenological stages of crop growth and development.

Chandel et al. (2003) found that sulphur application to Indian mustard (direct effect) significantly improved growth attributes, yield attributes, yield and quality up to 40 kg S/ha.

Giri et al. (2003) found that application of 45 kg S/ha resulted in the highest oil content of 41-44%. Sulphur application @ 20 kg/ha increased oil content in mustard over the control.

Mishra (2003) showed that mustard responded significantly at 40 kg S/ha and was 27.59% higher in seed yield and 37.64% higher in stover yield as compared to the yields at the control.

Singh and Singh (2003) reported that application of 54 and 72 kg S/ha gave significantly higher yield and quality of mustard.

Hidayatullah et al. (2004) studied that the application of sulphur produced a significant and consistent increase in oil content of mustard with increasing level of sulphur up to 21 kg/ha.

Jaggi (2004) reported a significant increase in oil content in seed of mustard with 25 kg S/ha, however, the oil yield of mustard was continued to increase up to 50 kg S/ha.

Naik and Rao (2004) recorded highest oil content of 40.8% in the sunflower following application of 40 kg S/ha as pyrite + farmyard manure. Further, application of 30 kg S/ha as SSP recorded the highest crude protein content of 25.4% and resulted in 14.3% increase over the control during both the years. The results of the present investigation find support from Kumawat et al. (2004).

Singh and Meena (2004) concluded that nitrogen @ 80 kg/ha + S @ 60 kg/ha significantly increased siliquae/plant, seeds/siliqua, length of siliqua, protein content, protein yield, S uptake and test weight of seeds and also resulted in highest seed (2109 kg/ha) yield on pooled basis.

Singh and Mukharjee (2004) reported that number of siliquae/plant, number of seeds/siliquae, test weight, seed yield, stover yield, harvest index, oil yield and protein content were increased with increasing rates of sulphur from the control to 45 kg S/ha in
mustard. However, Sharma et al. (2005) reported that the oil content in mustard increased up to 32.5 kg S/ha.

Singh et al. (2004) observed that application of 20 kg S/ha increased the oil content in mustard over the control. However, the oil yield and chlorophyll content were enhanced up to 40 kg S/ha.

Ahmad et al. (2005a) reported that sulphur application at different growth stages in mustard increased the growth and yield attributes significantly up to 40 kg S/ha.

Dongarkar et al. (2005) reported that plant height, number of branches, dry matter production was found significantly more with 75 kg N and 25 kg S/ha over rest of the doses. Results also revealed that yield attributes and yield of mustard significantly increased with 40 kg S/ha as compared to the control.

Harendra et al. (2005) noticed that the application of sulphur up to 60 kg/ha significantly increased the siliquae/plant, seeds/siliqua, 1000-seed weight, seed yield and stover yield of mustard.

Lanjewar and Selukar (2005) reported that it was found that increasing application of sulphur significantly increased the nutrient uptake and content of S up to 60 kg S/ha, which is followed by 40 kg S/ha appeared to be appropriate doses to increase the uptake.

Rana et al. (2005) evaluated that the yield attributes and seed yield of mustard increased with increasing the dose of sulphur, but the increase in seed yield was significant only up to 20 kg S/ha.

Sharma and Mehra (2005) reported that the pods/plant, pod length, seeds/pod, test weight and yield (seed and stover) significantly increased with each successive increase in sulphur level form 0 to 60 kg S/ha.

Singh and Dhiman (2005) found that leaf-area index, number of primary branches/plant and dry weight/plant (g) were increased with increasing rate of sulphur from 0 to 45 kg/ha in mustard.

Singh and Singh (2005a) reported that the application of 40 kg S/ha significantly increased the oil content in mustard over the control.

Singh and Singh (2005b) observed that with the increasing dose of sulphur significantly increased the protein content in seed of mustard.
Yadav et al. (2005) studied that the highest seed yield of mustard was recorded with basal application of 66 kg P and 30 kg S/ha.

Giri et al. (2006) revealed that application of 60 kg S/ha produced significantly higher seed yield and other growth parameters of mustard.

Kumar et al. (2006) noticed that oil content significantly increased with the application of sulphur, which was lowest in the control (38.62%) and the highest (40.82%) at 60 kg S/ha. The maximum oil yield was observed in the treatment where 40 kg S/ha was applied.

Mani et al. (2006) reported that sulphur increased plant height (162.33 cm) of mustard by 1.8% as the dose of sulphur increased from 0 to 30 kg S/ha.

Mehdi et al. (2006) conducted a field experiment with 4 levels of sulphur 20, 40, 60 and 80 kg/ha and reported that oil content and protein content in seed of mustard increased with application of 60 kg S/ha and it was decreased their after.

Piri and Sharma (2006) found that yield attributes, seed and straw yields, oil content and oil yield, and sulphur content and uptake in both seed and straw increased significantly with increasing level of sulphur up to highest level of 45 kg S/ha. Application of 15, 30 and 45 kg S/ha increased the seed yield over the control by 9, 16 and 23%; oil yield by 13, 22 and 33%; and sulphur uptake by 25, 48 and 65%, respectively.

Ramesh et al. (2006) observed that S application @ 65 kg S/ha significantly increased the number of siliquae/plant, number of primary branches/plant, length of silique, 1000-seed weight, seed yield and stover yield of mustard.

Basal application of S at the rate of 40 kg/ha increased the seed yield of mustard by 21.8% over basal application of N at the rate of 20 kg/ha (Vyas et al., 2006). These studies reported that yield of mustard was increased with 20 to 60 kg S additions/ha depending upon soil and environmental conditions.

Jat and Mehra (2007) reported that application of 40 kg S/ha and 5 kg Zn /ha significantly increased the seed and stover yield of mustard. Nitrogen, phosphorus, potassium and sulphur uptake increased significantly up to 60 kg S/ha and 5.0 kg Zn/ha application except nitrogen and potassium uptake in seed where significant increase was recorded only up to 40 kg S/ha.
Kumar and Yadav (2007) indicated that the application of 90 kg N and 30 kg S/ha significantly increased the seed yield, stover yield, oil content and protein content in seeds of Indian mustard.

Malviya et al. (2007) conducted a field experiment at Faizabad (Uttar Pradesh) during the year of 2002-03. They noticed that application of 60 kg S/ha showed slight improvement in production of siliquae/plant (336.78), number of seeds/siliqua (12.56), 1000-seed weight (5.03 g) and seed yield (16.78 q/ha), oil (41.20%) and protein content (20.02%) of mustard over those of 30 kg S/ha but the differences were not significant.

Mehdi and Singh (2007) reported that yield contributing characters i.e. 1000-seed weight, seed weight/plant, number of siliquae/plant, siliqua length and seed and straw yields were significantly increased as a result of S application up to 40 kg/ha.

Piri and Sharma (2007) revealed that both irrigation and 30 kg S/ha significantly increased the yield attributes and seed and straw yields of Indian mustard.

Saraswat and Singh (2007) observed that crop responded significantly up to 25 and 60 kg/ha of S and N, respectively.

Ceh et al. (2008) reported that application of 40 and 60 kg S/ha gave significantly higher yield of mustard over 20 kg S/ha and no S application. Mustard crop produces more seed yield of mustard (Chand and Goutam, 2009) as compared to without S.

Chaubey et al. (2008) found that the increase in oil content in seed of mustard was the highest with application of 40 kg S/ha while further increase in sulphur level did not affect the oil content in seed of mustard.

Jat et al. (2008) reported that application of 40 kg S + 25 kg ZnSO$_4$ + 50 kg FeSO$_4$/ha significantly increased the number of siliquae/plant, number of seeds/siliqua, test weight, seed yield, stover yield, oil content (%) and oil yield (kg/ha) of mustard.

Kumar and Kumar (2008) observed that the effect of different doses of sulphur (0, 20, 40 and 60 kg S/ha) on various developmental characters of mustard and observed that 50% flowering and 50% podding were started significantly earlier in the plots fertilized with sulphur as compared to the control, but the days taken to maturity were not affected due to sulphur application.
Makeen *et al.* (2008) studied that number of leaves, plant height and dry matter production were significantly influenced by sulphur application @ 60 kg/ha in Indian mustard.

Sardana *et al.* (2008) revealed that application of sulphur (20 and 40 kg S/ha) through gypsum as soil application, thiourea at 0.05 and 0.10% and sulphuric acid at 0.15% as foliar application, net return and benefit cost ratio were higher with basal application of 20 S/ha through gypsum + foliar application of thiourea (0.05 %), closely followed by spray of 0.15 per cent sulphuric acid and soil application of gypsum to supply of 40 kg S/ha.

Sarangthem *et al.* (2008) also confirmed that the seed yield of mustard significantly increased from 9.5 to 10.9 q/ha with the increase in level of sulphur from 0 to 40 kg/ha.

Singh *et al.* (2008a) reported that the application of 90 kg N and 30 kg S/ha significantly increased the seed, oil and protein yields, and protein content of seed.

Singh *et al.* (2008b) revealed that growth, yield attributes and seed as well as stover yields all these parameters were found to increase with increasing level of S up to 45 kg/ha and all above parameters were recorded significantly higher over control. Application of sulphur proved beneficial in increasing oil content reported by (Faujdar *et al.*, 2008).

Zizale *et al.* (2008) conducted field experiment on loamy sand soil of Anand (Gujarat) during the year 2003-04. They used “GM-2” variety of mustard for sowing. Result revealed that there was significant difference in seed and stover yield of mustard under different levels of S. The seed yield was significantly increased under all levels of sulphur over control. The $S_{45}$ (1898 kg/ha) was at par with $S_{30}$ (1812 kg/ha), produced significantly higher seed yield than $S_{15}$ and control $S_0$, the maximum stover yield was registered under $S_{45}$ (3920 kg/ha). The maximum S uptake (34.5 kg/ha) was recorded with 45 kg S/ha.

Sharma *et al.* (2009) found that maximum oil content of 38.4% was obtained with the application of 45 kg S/ha. On an average, oil content increased from 36.7 to 37.9% with the increase in level of S application from 0 to 45 kg S/ha.

Dabhi *et al.* (2010) observed the maximum growth, yield attributes and uptake of sulphur under 40 kg S/ha ultimately resulted in the highest seed yield of mustard, which was higher by 15.35% over the control.
Kapur et al. (2010) reported that highest number of primary and secondary branches/plant, number of siliqua/plant, number of seeds/siliqua, test weight and seed yield were recorded significantly higher with 60 kg S/ha. Higher straw yield was recorded with S fertilization @ 45 kg/ha. The increase in seed yield under S levels at 60, 45, 30 and 15 kg/ha was 45.0, 44.9, 41.0 and 23.0% over control.

Parmar et al. (2010) conducted a field experiment at Dantiwada (Gujarat) during the year of 2007-08. They reported that significantly the highest test weight (4.89 g), seed (17.22 q/ha) and stover yield (35.05 q/ha) of mustard was recorded with 45 kg S/ha. However, the control and 15 kg S/ha were found at par with each other.

Shelly and Virender (2010) studied that split application of S resulted in a significantly higher number of primary branches and siliqua/plant and seeds/siliqua. The higher seed yield was obtained with application of S as one fourth at sowing, one half at vegetative stage + one fourth at 50% flowering.

Singh et al. (2010b) noticed that mustard crop fertilized with 150-30-0.50 kg N-S-Zn EDTA /ha fetched the highest growth parameters, seed and stover yields, net returns with maximum benefit : cost ratio.

Thuan and Rana (2010) evaluated to genotypes of Indian mustard (B. Juncea) viz., ‘Pusa Mahak’ recorded higher number of siliqua/plant, test weight, number of seeds/siliqua with the application of sulphur @ 40 kg/ha and produced 19.3 % higher seed yield than the control.

Yadav et al. (2010a) reported that the maximum yield was obtained by the sulphur application @ 40 kg/ha.

Basumatary and Talukdar (2011) observed that highest oil content (41.3%) was obtained due to integration of 60 kg of S with 3.0 t FYM/ha and resulted in a 12.8% increase in oil content over the control.

Gangwar et al. (2011) conducted a field experiment and found that combined effect of 50 kg P₂O₅ and 40 kg S/ha with seed inoculation with PSB increased the growth parameters, seed and straw yield as well as nutrient content in seed and straw which resulted in higher nutrient uptake by mustard grown in loamy sand of North Gujarat.
Among the sulphur level, 45 kg S/ha being on par with 30 kg S/ha gave significantly higher seed yield (1.25 t/ha), stover yield, sulphur uptake (20.7 kg/ha) and oil and protein content (Kumar et al., 2011).

Mohiuddin et al. (2011) indicated that the plant height, branches/plant, siliquae/plant, seed yield and stover yield increased with increasing S levels significantly up to 24 kg S/ha.

Panchal et al. (2011) found that seed yield, protein and oil yields as well as N and S uptake of mustard increased significantly due to application of 100 kg N/ha and 40 kg S/ha individually as well as in combination over control.

Vaseghi et al. (2011) reported that canola cultivars reacted to sulfur fertilizer and oil concentration in their seed increased.

Verma et al. (2011) observed that fertilizers 120 kg N + 45 kg S/ha gave significantly higher plant height, number of primary branches/plant, number of secondary branches/plant, dry matter accumulation/plant, siliquae length, number of siliquae/plant, number of seeds/siliqua, 1000-seed weight, grain yield, stover yield, harvest index and protein content (%) than other levels of fertilizers (control, 40 N + 15 S and 80 N + 30 S kg/ha) during both the years.

Baudh and Prasad (2012) indicated application of 60 kg S/ha in the combination with Zn influenced the root length, shoot length, number of leaves/plant, number of branches/plant and crop growth rate and the productivity such as biomass production, number of siliquae/plant and seed output also increased with increasing levels of S and Zn.

Chattopaddhyay and Ghosh (2012) reported that seed yield of mustard increased significantly with increased levels of S up to 45 kg S/ha, which was found at par with 60 kg S/ha.

Jat et al. (2012) reported that all the yield attributes (siliquae /plant, seeds/siliqua and test weight), seed and stover yield increased significantly with increasing rates of sulphur up to 40 kg/ha. The seed yield increased by 24.8 per cent over control.

Jyoti et al. (2012) found that the oil content, crude protein and soluble protein were significantly influenced by 30 kg S/ha. The highest seed and stover yield of rapeseed (cv ‘B-9’) was 910 and 4320 Kg/ha, respectively found under the application of 30 Kg S/ha.
through SSP, resulting in a 41.9 and 18.9% increase in the yield over that of the control during both of the years.

Kumar and Trivedi (2012) revealed that seed and straw yield, oil content and protein content significantly increased with increasing level of sulphur up to the highest level of 60 kg S/ha. Application of 20, 40 and 60 kg S/ha increased the seed yield over the control by 13.95, 28.11 and 28.47%. Data related to the oil content of seed showed that the application of 60 kg S/ha increased the oil content by 7.84, 4.87 and 3.93% over 0, 20 and 40 kg S/ha respectively. The highest seed protein (23.86%) was recorded due to application of 60 kg S/ha and decreasing levels of S led to significant decreasing in this bio-chemicals parameter of mustard.

Pachauri et al. (2012) reported that the plant height and dry weight of plant increased significantly with each increment in the dose up to 60 kg/ha. Mean seed yield of mustard recorded under 90 kg S/ha which were higher by 30.67, 21.18 and 3.76 per cent over 0, 30 and 60 kg S/ha, respectively.

Singh et al. (2012a) noticed that application of 60 kg S/ha gave significantly higher plant height, number of branches plant, maximum oil content (%) and protein content (%) in seed.

Singh et al. (2012b) found that the variety ‘Rohini’ gave higher plant height, number of branches/plant, siliquae/plant, seeds/siliqua, 1000-seed weight, harvest index and resulted significantly higher seed and stover yield, oil and protein content with the application of 60 kg S/ha over all other levels of sulphur application and the control.

Singh et al. (2012c) noticed that yield estimates, protein percentage and uptake of N and S in mustard improved significantly with S application. The oil content increased with S level but reduced at higher level of N (80 kg/ha). Uptake of P and K by mustard increased with graded levels of nitrogen and sulphur.

Verma et al. (2012) evaluate the effect of sulphur (0, 20, 40 and 60 kg S/ha), zinc (0, 5 and 10 kg Zn/ha) and boron (0, 0.5 and 1.0 kg B/ha) levels on quality, economics and uptake of nutrients by mustard [Brassica juncea (L.)]. Results revealed that application of 60 kg S/ha gave significantly higher seed yield, oil yield and protein content (%) in seed. On economic basis, the highest profit was recorded with combined use of 60 kg S +5 kg Zn and 1.0 kg B/ha.
Charan et al. (2013) studied that application of 60 kg S/ha encouraged growth, yield and yield contributing characters of mustard economically, uptake of nutrient (NPK and S kg/ha) and oil content of seed.

Dubey et al. (2013) observed that application of 60 kg S/ha and 10 kg Zn/ha, produced significantly higher plant, primary and secondary branches/plant, number of leaves/plant, days taken to flowering, days taken to maturity, number of siliqua/plant, length of siliqua, and number of seeds/siliqua, harvest index and oil content. However, dry matter accumulation/plant, 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.

Sah et al. (2013) conducted field experiment at Aligadh (U.P) during the year 2004-05. They reported that application of sulphur resulted into significant variation in the growth characters of mustard. Contrary to this, highest dose of sulphur i.e. 45 kg S/ha produced higher plant height (204.13 cm) number of functional leaves at 90 DAS (19.66), LAI at flowering (19.66), number of branches/plant (9.45), dry matter (140.68 gm per plant), number of siliquae/plant (341.77), test weight (5.14 g), seed (19.23 q/ha), stover yield (36.30 q/ha) and oil content (40.05%) over control.

Tetarwal et al. (2013) reported from application of sulphur 30 kg/ha in the form of bentonite sulphur recorded significantly higher plant height, dry matter/plant, number of primary and secondary branches/plant over gypsum and wettable sulphur after mixing in the soil.

Katiyar et al. (2014) observed that application of sulphur had significant influence on yield attributes, grain & oil yield of mustard. Maximum values of plant height (150.2 cm), seeds per pod (17), thousand grain weight (6.54 g), grain yield (21.94 q/ ha) and oil content (42.4 %) were recorded with dual application basal along with 80 % WP @ 1.25 kg/ ha foliar sprayed at 75 DAS closely followed by application sulphur basal + 80 % WP @ 5 kg/ ha applied with urea broadcasting at 45 DAS.

A field experiment was conducted at Udaipur during rabi season of 2011 to study the effect of sulphur on yield, quality and nutrient uptake of mustard genotypes. The results revealed that among genotypes, ‘NRCDR-2’ recorded 15.46, 9.84, 2.78 and 19.16, 12.36 and 21.95% significantly higher in seed yield, stover yield, oil content, and total N, P and S uptake than genotype ‘Laxmi’. Application of 40 kg S/ha recorded significantly higher
Review of literature

Seed yield (1965.42 kg/ha) and stover yield (7092.60 kg/ha), N and S uptake over 20 kg S/ha and no sulphur (Neha et al., 2014).

Parihar et al. (2014) studied that there is progressive increase in levels of sulphur from control to 40 kg/ha resulted significant improvement in growth and yield attributes. Seed yield and net returns during the crop season, it represented the seed yield 15.98 q/ha that was 8.9 and 24.02 per cent higher than 20 kg/ha and control, respectively.

Piri et al. (2014) noticed that number of siliquae/plant, siliqua length, seeds/siliqua, 1000-seed weight, oil content and protein content significantly increased with increasing the rates of S up to 45 kg S/ha in Indian mustard.

Ray et al. (2014) reported that application of sulphur @ 60 kg S/ha had significant beneficial effect on various growth parameters of mustard viz., plant height at 75 DAS and at harvest, LAI and dry matter accumulation, which was found at par with 45 kg S/ha.

Singh and Kumar (2014) revealed that application of 120 kg N/ha and 45 kg S/ha was the best combination for getting higher seed yield, siliquae/plant, siliqua length, number of seed/siliqua, harvest index, higher protein content (%) and oil content in seed of mustard.

Kumar et al. (2015) noticed that application of sulphur @ 60 kg/ha showed their significant superiority in various yield attributing characters and yield of mustard like as number of siliquae/plant (553.1), number of seeds per siliqua (15.12), 1000-seed weight (4.09 g), seed yield (1583 kg/ha), stover yield (6105 kg/ha), oil content (39.40%), oil yield (625 kg/ha), protein content (26.90%) and protein yield (426 kg/ha) found statistically at par with application of sulphur @ 40 kg/ha.

Ray et al. (2015) noticed that yield attributes and yield of mustard were highest with 60 kg S/ha, mostly at par with 45 kg S/ha. The erucic : oleic acid ratio was inversely related to the subsequent increase in S doses, thereby suggesting the qualitative improvement of oil with S application.

Choudhary et al. (2016) concluded that planting of pearl millet and mustard in zero tillage with 4 t/ha crop residue along with 30 kg S/ha through gypsum could be recommended for realizing higher system productivity and profitability. It also improved soil organic carbon and soil physical properties.
Jadav et al. (2016) revealed that different levels of sulphur significantly improved the growth, yield as well as uptake of nutrients by seeds and straw of mustard. Combined effect of 50 kg P\textsubscript{2}O\textsubscript{5}/ha and 40 kg S/ha with seed inoculation with PSB gave higher seed and straw yield as well as nutrient content in seed and straw which resulted in higher nutrient uptake by mustard grown in loamy sand of North Gujarat.

Kumar et al. (2016b) concluded that the highest seed yield (2606 kg/ha) was obtained in T\textsubscript{7} (60 kg/ha S and 120 kg/ha N) followed by T\textsubscript{6} (40 kg/ha S and 120 kg/ha N) treatment which gave 2588 kg/ha seed yield. Oil content progressively increased with increase of S level with N highest (41.73%) with S level of 40 kg/ha.

Mishra et al. (2016) conducted a field experiment with “Pusa Mahak” variety of mustard grown in randomized block design with three replications and different treatment combination. They evaluated that application of 25 kg S/ha & 5 kg Zn/ha along with NPK under rainfed condition of chitrakoot found useful for obtaining higher seed yield of mustard crop

Pal and Pathak (2016) observed significant increase in oil content was observed during both the years and maximum increase was obtained in P\textsubscript{80}S\textsubscript{60} + compost + PSB which was 3.55% and 5.5% higher over control during the first and second year respectively. Economic analysis of IPNM treatments revealed that, highest B : C ratio (3.34) and VCR (2.34) were found in P\textsubscript{80}S\textsubscript{60}+ Compost + PSB treatment.

After conducting an experiment in rabi season of 2009-10 at Lakhoti (Uttar Pradesh), Singh and Thenua (2016) reported that application of sulphur @ 40 kg/ha registered significantly higher plant height (145.12 cm), number of primary (6.51) and secondary (10.58) branches/plant, dry weight (28.95 g/plant), total uptake of N (39.34 kg/ha), total uptake of P (10.67 kg/ha) and total uptake of S (17.73 kg/ha) of mustard as compared to other levels of sulphur application viz., 0 & 20 kg/ha.

Singh et al. (2016b) concluded the highest values for siliquae on main shoot, siliquae/ plant, 1000-seed weight, plant height, LAI, seed and stover yield were found associated with the mustard variety ‘Giriraj’ with application of 60 kg S/ha which were at par with application of 30 kg S/ha in except siliquae on main shoot and stover yield. Application of 60 kg sulphur resulted in 8.20 and 7.92% increase in seed and stover yield over the control.
Lakshman *et al.* (2017) found that the treatment with 40 kg/ha has recorded significantly higher number of siliqua/plant (204.9), seeds/siliqua (14.47), test weight (5.73g), oil content (38.90%) and oil yield (711.07 kg/ha) of mustard seed compared to control and 20 kg/ha sulphur application.

Negi *et al.* (2017) observed that significant increase in number of branches/plant, number of siliqua per plant, test weight and straw yield over control were recorded by 60 kg S/ha applied through zypmite. Grain yield showed numerical increase of 14.50% over control with 60 kg S/ha applied through zypmite.

Singh *et al.* (2017c) reported that the application of 40 kg S/ha was significant over other sulphur levels in terms of growth parameters, yield attributes and yield and profitability of mustard crop cultivation.

Rajput *et al.* (2018) found that the growth characters such as plant height, number of primary and secondary branches/plant, number of leaves/plant and dry matter accumulation/plant were maximum at 120 kg N/ha and 60 kg S/ha. In case of sulphur application the maximum seed yield (18.89 and 18.08 q/ha) and stover yield (58.38 and 55.16 kg/ha) was recorded at 60 kg S/ha, which was at par with 40 kg S/ha.

The field experiment was carried out at Department of Soil Science, Allahabad, India during *rabi* season. The experiment was laid out in 3 × 3 factorial randomized block design with 9 treatments in three replications. Upadhyay *et al.* (2018) observed that the growth characters in treatment T9 (@ 45 kg S/ha + 5.5 kg zinc/ha) was found to be significant in respect to plant height, no. of leaves/plant, dry weight of plant, no. of primary and secondary branches/plant.

A field experiment was conducted during the winter season of 2013-14 at the Crop Research Farm, Allahabad (U.P.) From the results of the experiment, Verma and Dawson (2018) revealed that the maximum no. of siliquae/plant (144.86), no. of seeds/siliqua (41.60), test weight (3.18 g), seed yield (1.74 t/ha), harvest index (41.90%) and oil content (44.21%) observed in the treatment T5 (sulphur 30 kg/ha and boron 2 kg/ha with line sowing). The maximum stover yield (2.70 t/ha), net return (22899.32 ₹/ha) and benefit cost ratio (1.82) obtained in the treatment T7 (sulphur 15 kg/ha and boron 1 kg/ha with broadcasting).
2.3 INTERACTION EFFECT OF POTASSIUM AND SULPHUR

Varma et al. (2002) determined the effect of sulphur (15, 30, and 45 kg/ha) and potassium (20, 40, and 60 kg/ha) on yield and oil content of Indian mustard. Sulphur significantly increased seed and stover yields, oil content, and yield attributing characters of Indian mustard such as siliquae/plant, seeds/siliqua, length of siliqua and test weight only up to 30 kg/ha. Potassium application up to 40 kg/ha had a significant improvement of seed and stover yields, and siliquae/plant compared to 20 kg/ha but was at par with 60 kg/ha.

Misra (2003) assessed effect of sulphur (0, 20, 40 and 60 kg S/ha) and potassium (0, 30, 60 and 90 kg K_2O/ha) on mustard crop (cv. Varuna). Results showed that mustard crop responded significantly to the application of S and K_2O. The seed and stover yields increased in the linear order up to 40 kg S and 60 kg K_2O/ha. The highest seed yield (2035 kg/ha) at 40 kg S/ha was 27.59% higher in comparison to the yield at control. Similarly, application of 60 kg K_2O/ha produced highest seed yield (2085 kg/ha) which was 35.48% higher in comparison to the yield in control. The P uptake significantly increased up to 40 kg S/ha and thereafter, decreased significantly. Percent utilization of added K and S was maximum when lowest levels of K and S were applied. Oil, protein, total S amino acid contents, fatty acids composition; oleic and linoleic acid contents increased significantly with the application of S and K and erucic acid decreased showing improved quality of mustard oil.

Gundalia et al. (2005) evaluated response of mustard cv. Varuna to different carriers of S (applied @ 30 kg/ha) and K (@ 75 kg/ha) along with FYM at 25 t/ha. The highest grain yield was recorded in T_8 (1102 kg/ha), T_2 (1084 kg/ha) and T_9 (1073 kg/ha), which were at par with each other but significantly superior to the control (738 kg/ha). The stover yield also increased significantly with NP, NPS and K additions. The availability of P, K and S in the soil after harvest of the crop increased significantly with all the treatments, whereas the organic C content increased significantly with FYM only. The S contents in grain and stover increased significantly with the different treatments. Significantly the highest total uptake of P, K and S was noticed with K_2SO_4 only.

Krisha et al. (2005) reported significant increase in the grain yield, oil per cent in Indian mustard cv. Varuna with application of 60 kg P + 60 kg S/ha + 30 kg Zn/ha, uniform doses of 80 kg N/ha and 40 kg K/ha.
Akter et al. (2007) found that application of Boron 2 kg/ha in mustard crop with blanket application of fertilizers dose of 120 kg N + 35 kg P + 75 kg K + 30 kg S + 5 kg Zn/ha increased the yield and yield component.

Chand (2007) conducted an experiment using split plot design at udaipur, found that the application of FYM @ 10 t/ha, along with 45 kg N : 30 kg P : 15 kg K : 30 kg S/ha, and inoculation of Bacillus megaterium var. phosphaticum + Azotobacter Chroococcum co-inoculation increased stover yield, oil yield, highest seed yield, B : C ratio, N, P, K and S uptake. Fertilizers 45 : 30 : 15 : 30 kg NPKS/ha application along with inoculation of A. chroococcum increased seed yield of mustard by 23 per cent over control.

Halder et al. (2007) noticed significant increase in the seed yield of mustard var. BARI Sarisha-6 with application of 2 kg B/ha long a blanket rate of 120 kg N + 35 kg P + 65 kg K + 20 kg S + 5 kg Zn and cow dung at 5 t/ha.

Chaubey et al. (2008) indicated that the highest seed yield was recorded with 100% NPK + 5 t FYM + 40 kg S + Azotobacter in mustard crop.

Rana et al. (2008) reported that the application of 120 kg N + 40 kg P + 20 kg K + 40 kg S + 30 kg Zn and 2 kg B/ha increased number of siliquae/plant, number of seeds/siliqua, 1000-seed weight, stover yield and seed yield significantly over no fertilizer application.

Gavade and Shigvan (2009) concluded that the application of sulphur @ 40 kg/ha, potassium @ 60 kg/ha and micronutrient complex generated maximum free proline content and significantly increased the yield of mustard compared with absolute stress control and even higher than irrigation control. The application of sulphur + potassium was another promising combination as it produced 10.37 q/ha seed yield.

Khatkar et al. (2009) observed that application of 100 kg N/ha + 60 kg K2O/ha + 30 kg S/ha with blanket application of potash at 40 kg/ha significantly increased highest plant height (190.39 cm), number of branches/plant (20.20), number of leaves/plant (48.70), dry weight (48.80 g/plant), number of siliquae/plant (383.67), number of seed/siliqua (20) and test weight (5.10 g) of mustard.

Singh et al. (2010a) reported that Indian mustard variety 'NRCHB-10' fertilized with 100% recommended dose of fertilizer (80 kg N, 40 kg P2O5, 40 kg K2O and 30 kg S/ha) can be used to achieve higher growth, yield attributes and yield and better resource utilization with maximum profit in late sown condition.
Singh et al. (2010c) revealed that quality parameters like oil and protein content in seed and their yield were influenced significantly by various fertility levels. Oil content increased significantly with increasing fertility level up to 100% RDF (80, 40, 40, 30 kg NPKS/ha) and thereafter decreased with increase in fertility. However, protein content increased with increasing in fertility level and recorded the highest value at 150% RDF (F3). The uptake of N, P, K and S by seed and stover of crop increased concurrently with increasing fertility level and maximum were recorded at the highest fertility level.

Amanullah and Sukhdevs (2011) conducted experiment having twenty treatments in a randomized complete block design were consisted of two oilseed rape (B. napus canola) and mustard (B. juncea canola) genotypes at three rates each of S (15, 30, and 45 kg S/ha) and K (30, 60, and 90 kg K/ha) fertilizers plus one control (no S and K applied). It is concluded that a combination of 60 kg K + 30 kg S/ha would improve seed yield and yield components of rape and mustard in the study area and contribute significantly to increased production.

Singh and Pal (2011) found that significantly increased seed yield, biological yield and stover yield of Indian mustard with application of recommended dose of fertilizer i.e. 120 kg N + 17.6 kg P + 16 kg K + 40 kg S + FYM 10 t/ha.

Tripathi et al. (2011) noticed that application of 100 % (120-40-20 kg N-P2O5-K2O/ha) recommended dose of fertilizers along with + 2 t FYM + 40 kg S + 25 kg ZnSO4 + 1 kg B/ha + Azotobacter (seed treatment) resulted in maximum plant height, dry matter accumulation, total branches/plant, siliquae/plant, seeds/siliqua, 1000-seed weight, protein content, net returns, B : C ratio and higher seed yield.

Chaplot et al. (2012) reported significantly increase plant height, branches/plant, dry matter accumulation/plant, siliquae/plant, seeds/siliqua and test weight with cojoint application of 60 kg N + 40 kg P + 40 kg K + 40 kg S + 5 kg Zn/ha in mustard variety Bio-902 over Vasundhara.

Singh et al. (2012) observed that oil content increased significantly in mustard crop with application 60 kg K2O and 40 kg S/ha.

A field experiment was conducted on mustard cv. Roheen, application of 120 : 60 : 30 : 45 : 30 kg N : P : K : S : Zn/ha significantly improved highest seed yield (2465 kg/ha), stover yield (5350 kg/ha), test weight (5.4 g), protein content (20.3 %), oil content (39.5 %), protein yield (499 kg/ha) and oil yield (973 kg/ha) over control (Sharma, 2013).
Mandal and Chattopadhyay (2014) studied that seed yield, stover yield and oil yield of mustard varied significantly under varying levels of fertility. Crops receiving 140 kg N, 175 kg P₂O₅, 112 kg K₂O, 1.12 kg B and 16.80 kg S produced the maximum seed yield (1.69 t/ha, 1.65 t/ha and 1.61 t/ha during 2002-03, 2003-04 and 2004-05 respectively). Highest production of mustard during all the three years of study, showed highest removal of N, P and K by the crop which amounted to, on an average, 138.58 kg N/ha, 73.78 kg P/ha and 164.37 kg K/ha, respectively.

Yeshpal et al. (2014) reported an application of RDF of 100% NPK in combination with FYM, Azotobacter and sulphur recorded a higher nutrient content and nutrient uptake. Maximum nutrient uptake was noticed with 100% RDF of NPK + FYM + Azotobacter + sulphur. However, a maximum P uptake was recorded in the treatment comprising 100% RDF of NPK + FYM + sulphur.

Amanullah and Khan (2015) conducted a field experiment consisted of 20 treatments having two Brassica species [rape (B. napus) and Indian mustard (B. juncea)]. From the results, It was concluded that a combination of 60 kg K₂O + 30 kg S/ha could improve dry matter accumulation and seed yield of rapeseed and Indian musard.

Rathore et al. (2016) revealed that application of 100% NPK + 25 kg ZnSO₄ resulted in significantly higher plant height and seed yield than control, 50% NPK and 100% N.

Singh and Godara (2016) concluded that application of 5 t/ha FYM to pearlmillet and recommended dose of N & P along with 30 kg potash, 100 kg gypsum, 10 kg zinc sulphate and 10 kg ferrous sulphate to mustard is necessary for getting higher yield and net returns from pearlmillet-mustard cropping system.

The field experiment was conducted at Agronomy Research Farm, Faizabad during the rabi season of 2011-12 consisting of 15 treatment combinations laid out in randomized block design. Singh et al. (2016a) observed that Narendra Rai-1 with the application of 120 kg N/ha + 60 kg P₂O₅/ha + 40 kg K₂O/ha + 40 kg S/ha + 5 kg Zn/ha + 0.2% Boron spray recorded significantly higher growth and yield attributes as well as yield and oil content as compared to Narendra Ageti Rai- 4.

Dhruv et al. (2017) observed that the application of 120 kg N + 60 kg P + 40 kg K + 40 kg S/ha significantly increased plant height (171.91 cm), number of branches/plant (11.94), number of siliqua/plant (301.00), number of seeds/siliqua (16.20), number of seeds/siliqua (16.20),
Review of literature

fresh weight/plant (104.44 g), dry weight/plant (37.45 g), test weight (3.96 g), seed yield (2.20 t/ha), straw yield (4.51 t/ha) and oil content (37.67%). Highest B : C ratio (2.36) was recorded in T3 (@ 60:30:20 kg NPK/ha + 0 kg S/ha).

Kumar et al. (2017) reported that the highest plant height (174.63 cm), number of branches/plant (24.47), dry weight (21.47 g), number of siliquae/plant (381.40), 1000-seed weight (5.52 g), seed yield (1541.5 kg/ha) and stover yield (5161.0 kg/ha) was recorded the application of 75% NPK in combination with 40 kg S and 10 MT FYM/ha. Net return (₹ 33119.4) and B: C ratio (1.04) was significantly differ from control. Oil and protein content was significantly influenced with the application of 75% NPK along with 40 kg S and 10 MT FYM/ha.

Sahoo et al. (2017) noticed that significantly maximum seed and stover yield was recorded under treatment 75% STR + FYM @ 5 t/ha + Zn @ 5 kg/ha + Azotobacter (T6). The seed and stover yield of mustard significantly increased by 68.44 and 36.46 per cent, respectively over control. The highest total uptake of N, P, K, S and Zn were recorded with T6 treatment which were 89.08, 65.35, 80.25, 94.11 and 77.78 per cent higher over control. The highest oil content and oil yield were registered with 50% STR + FYM @ 5 t/ha + Zn @ 5 kg/ha + Azotobacter (T9) which was at par with T6 (75% STR + FYM @ 5 t/ha + Zn @ 5 kg/ha + Azotobacter).

Singh et al. (2017a) revealed that treatment containing 100% RDF of NPK + FYM 5 MT/ha + 40 kg S/ha recorded significantly highest mustard grain yield (17.96 q/ha), protein content (21.06%), oil yield (6.72 q/ha) and uptakes of nitrogen (60.53 kg/ha), phosphorus (7.6 kg/ha), potassium (13.47 kg/ha) and sulphur (21.01 ppm) by mustard seed were significantly highest with this treatment, whereas treatment consisting 100% RDF of NPK + sulphur 40 kg appeared to be more promising to gave significantly and highest stover yield (43.7 q/ha), oil content (37.66 q/ha) and uptakes of nitrogen (47.42 kg/ha), phosphorus (8.02 kg/ha), potassium (60.09 kg/ha) and sulphur (15.21 ppm) by mustard stover over other treatments.

Singh et al. (2017b) found that mustard variety cv. Narendra Rai-1 application of 120 kg N + 60 kg P2O5 + 40 kg K2O + 40 kg sulphur + 5 kg Zn + 0.2% Bo spray before flowering (F5) recorded significantly higher plant height (except 30 DAS), primary branching, yield and oil content over rest of the treatments but remained at par with 120 kg N + 60 kg P2O5 + 40 kg K2O + 40 kg S + 5 kg Zn/ha (F4).
A field experiment was conducted at Allahabad during rabi season of 2014-15. Swamy et al. (2017) found that soil chemical properties, growth parameters, yield and oil content increased significantly in treatment T₈ - [i.e. N @ 80 kg/ha + P @ 60 kg/ha + K @ 40 kg/ha & S @ 40 kg/ha and FYM 10 t/ha].

Thaneshwar et al. (2017) indicated that significantly better growth attributes, yield attributes and grain yield (22.75 q/ha) was obtained with combined application of RDF (120:60:40:30 kg NPKS/ha) + vermicompost @ 5.0 t/ha over rest of the treatments. The minimum grain yield (19.15 q/ha) was received in treatment RDF (120:60:40:30 kg NPKS/ha). The application of RDF + vermicompost @ 5.0 t/ha was also found significantly higher gross income (₹ 81575/ha) and net profit (₹ 35725/ha) over rest of the treatments. While B : C ratio was significantly higher (1.96) with application of RDF (120:60:40:30 kg/ha NPKS) over rest of the treatments except at par with RDF + vermicompost @ 2.0 t/ha.