Soil fertility is an important factor for augmenting crop production. Normally, fertilization to the crops is done through supplying nitrogen, phosphorus and potassium. Other nutrients are applied either in intensive cropping or in pockets wherever those are deficient. Sulphur, as a plant nutrient, is becoming important for Indian agriculture in recent years. Its dynamics in soil and reactions in plant are similar to N, it requires by plants in amount similar to P and in terms of monetary value, it can be compared with K (Tandon, 1986). Sulphur has come out as a master nutrient for increasing the production of oilseed crops.

Sulphur, a secondary nutrient is required by plants in almost equal amount as phosphorus. There are considerable evidences indicating very good response of applied sulphur to sesamum.

The present investigation was undertaken with a view to know the “Effect of sulphur and boron on summer sesamum (Sesamum indicum L.) under medium black calcareous soil”. Attempts are made in this chapter to review the recent research work relating to the aspects under study. The review pertaining to the research work was made under the following heads.

2.1 EFFECT ON GROWTH, YIELD ATTRIBUTES AND YIELD

2.1.1 EFFECT OF SULPHUR ON GROWTH, YIELD ATTRIBUTES AND YIELD

Nagavani et al. (2001) conducted an experiment on effect of nitrogen and sulphur on yield of sesame on sandy clay loam soils in Tirupati and reported that application of sulphur @ 40 kg ha\(^{-1}\) increased number of capsules plant\(^{-1}\) and grain yield over control and 20 kg S ha\(^{-1}\) and further increase in the level up to 60 kg S ha\(^{-1}\) was not significant.
Allam (2002) studied the effects of gypsum (0, 500, and 1000 kg feddan\(^{-1}\)) and spacing (10, 20, and 30 cm) on sesame cv. Giza 32 in Assiut, Egypt, in 2000 and 2001. Gypsum was applied during sowing and 55 days after sowing. Increasing gypsum rates increased plant height, length of fruiting zone, number of branches and capsules per plant, seed yield per plant.

Dayanand et al. (2002) conducted an experiment on effects of sulphur on yield and food value of sesame (Sesamum indicum) and reported that biomass production, of sesame was increased significantly with increasing sulphur levels up to 60 kg ha\(^{-1}\).

Sarkar and Banik (2002) conducted an experiment on sesame during spring at Calcutta to study the effects of sulphur application at the rate of 0, 25 and 50 kg ha\(^{-1}\) on the growth and productivity of Sesame and reported that application of 50 kg S ha\(^{-1}\) was more effective in improving number of seed capsules\(^{-1}\) and leaf area index over application of 25 kg S ha\(^{-1}\).

Sharma and Gupta (2003) conducted an experiment on sesame during kharif season at Jobner on sandy loam soils with four levels of sulphur i.e. 0, 20, 40 and 60 kg ha\(^{-1}\) and reported that with increases the sulphur levels the plant height and dry matter yield was increased significantly, which was on par with application of 60 kg sulphur ha\(^{-1}\).

Vaijapuri et al. (2003) evaluate the effects of sulphur (0, 15, 30 and 45 kg ha\(^{-1}\)) and organic amendments (10 t ha\(^{-1}\) each of farmyard manure, poultry manure and press mud) They found that application of 45 kg S ha\(^{-1}\) gave the best result in terms of yield and yield attributing characters.

Saren et al. (2004) revealed that application of sulphur increased leaf area index over control in sesame. Increase in sulphur level with increasing leaf area index and grain yield was observed up to 45 kg S ha\(^{-1}\) during summer season in West Bengal.

Khare et al. (2005) reported that application of 20 kg S ha\(^{-1}\) significantly increased plant height and number of primary branches plant\(^{-1}\) over 10 and 30 kg S ha\(^{-1}\) in sesame during kharif season in Madhya Pradesh.

Rana et al. (2005) revealed that application of 40 kg sulphur ha\(^{-1}\) significantly increased number of branches plant\(^{-1}\) over application of 20 kg sulphur ha\(^{-1}\) in Indian mustard during rabi season on sandy loam soils of New Delhi.

Duary and Mandal (2006) conducted an experiment on response of summer sesame to varying levels of sulphur i.e. 20, 40, 60 kg S ha\(^{-1}\) and reported that plant
height, number of capsules plant\(^{-1}\), number of seed capsules plant\(^{-1}\) and grain yield was increased significantly with application of 40 kg S ha\(^{-1}\) and it was significantly superior over control, 20 and 60 kg S ha\(^{-1}\) on sandy loam soils in West Bengal.

Maragatham et al. (2006) observed the effects of sulphur at 0, 20, 40, 60 and 80 kg ha\(^{-1}\) applied alone or in combination with farmyard manure on seed yield of sesame. Application of sulphur at 40 kg ha\(^{-1}\) resulted in the highest grain yield and dry matter plant\(^{-1}\).

Raja et al. (2007) observed that application of 45 kg S ha\(^{-1}\) significantly increased number of branches plant\(^{-1}\) of sesame over application of 15, 30, 60 kg S ha\(^{-1}\) in sandy clay loam soils during summer season in Tamil Nadu, India.

Tripathi et al. (2007) conducted a field experiment during 2003 to 2005 on sulphur deficient clay loam soil. Four levels of sulphur were applied to sesame cv. JTS-8 through single super phosphate, elemental sulphur and gypsum. The results revealed that growth, yield attributes and yield were influenced with increasing levels of sulphur. Application of 45 kg S ha\(^{-1}\) through single super phosphate was found more economical followed by 30 and 15 kg S ha\(^{-1}\). Single super phosphate was found to be a relatively better source of sulphur than gypsum and elemental sulphur.

Kundu et al. (2008) revealed that combined application of 40 kg S ha\(^{-1}\) along with recommended dose of fertilizer (60: 30: 30 kg N, P, K ha\(^{-1}\)) significantly increased the number of capsules plant\(^{-1}\) over control, 20, 60 kg S ha\(^{-1}\) along with application of RDF of sesame during pre-kharif season on sandy loam soils of West Bengal.

Deshmukh et al. (2010) conducted an experiment on sesame (Sesamum indicum L.) in clay loam soils of Jabalpur during kharif revealed that application of 45 kg S ha\(^{-1}\) reported significantly higher seed yield and stover yield over application of 15 and 30 kg S ha\(^{-1}\) with different sources of sulphur.

An experiment conducted to study the effect of different levels of sulphur on potassium on growth, yield and yield attributes of sesame during kharif season in Gujarat and revealed that application of 40 kg S ha\(^{-1}\) obtained significantly higher plant height, number of capsules plant\(^{-1}\), number of seed capsules plant\(^{-1}\), number of branches plant\(^{-1}\) and grain yield and it was on par with application of 20 and 50 kg S ha\(^{-1}\) (Jadav et al. 2010).

Vaghani et al. (2010) reported that plant height, number of branches plant\(^{-1}\), number of capsules plant\(^{-1}\) and grain yield was increased significantly with application
of 40 kg S ha\(^{-1}\) and it was par with application of 20 kg S ha\(^{-1}\) in medium black calcareous soils during *kharif* season at Junagadh.

An experiment conducted during *spring* season at Allahabad on effect of sources and levels of sulphur and spacing on the growth and yield of spring sunflower on sandy loam soils with different sulphur levels *i.e.* 10, 20, 30 kg S ha\(^{-1}\) revealed that application of sulphur 30 kg ha\(^{-1}\) increased leaf area index over control, 10, 20 kg S ha\(^{-1}\) (Kumar *et al.*, 2011).

Shah *et al.* (2011) conducted an experiment on sulphur fertilization on improvement of sesame productivity and economic returns under rainfed conditions and revealed that application of sulphur 45 kg ha\(^{-1}\) significantly increased seed and stover yield over control, 30 and 60 kg S ha\(^{-1}\).

Significant increase in plant dry matter was observed with increasing sulphur level from 0 to 20 kg S ha\(^{-1}\) in sesame (Mondal *et al.*, 2012) beyond this limit there was decrease in total dry matter plant\(^{-1}\) was observed in Bangladesh.

A field experiment was conducted by Mathew *et al.* (2013) at Onattukara (Kerala) to study the effect of varying levels of sulphur (0, 7.5, 15 and 30 kg ha\(^{-1}\)) on yield attributes and yield of sesame. The results revealed that sesame responded significantly to the application of sulphur upto 30 kg ha\(^{-1}\) for yield attributes such as number of capsules per plant and dry weight of capsule of sesameum.

Significantly higher plant height, dry matter yield and leaf area index was observed in sunflower with application of sulphur @ 30 kg ha\(^{-1}\) over control and 15 kg S ha\(^{-1}\) during *kharif* season on sandy loam soils at Rajendranagar (Pavani *et al.*, 2013).

Tahir *et al.* (2014) revealed that plant height was increased significantly with increasing sulphur level. Application of 50 kg S ha\(^{-1}\) recorded highest plant height, number of capsules plant\(^{-1}\), and number of seed capsules\(^{-1}\) over control, 10, 20, 30 and 40 kg S ha\(^{-1}\) in sesame during *summer* season on sand clay loam soils of Pakistan.

An experiment was conducted by Thentu *et al.* (2014) at Agriculture College, Nagpur during summer season of 2011-2012. They observed that application of 40 kg S ha\(^{-1}\) recorded maximum and significantly higher number of capsules plant\(^{-1}\), number of grains capsule\(^{-1}\), seed yield plant\(^{-1}\) and dry matter accumulation. Seed yield was recorded maximum in 40 kg S ha\(^{-1}\) (471 kg ha\(^{-1}\)) and was at par with 30 kg S ha\(^{-1}\) (465 kg ha\(^{-1}\)).
An experiment on growth, yield and quality of summer sesame as influenced by fertilizer and sulphur levels of Sesame during summer season in Nagpur and reported that application of 40 kg S ha$^{-1}$ increased number of capsules plant$^{-1}$ and number of grains capsule$^{-1}$ over control, 10, 20, 50 kg S ha$^{-1}$ which was on par with application of 30 kg S ha$^{-1}$ (Tulasi et al., 2014).

Verma et al. (2014) conducted a field experiment on four levels of sulphur (0, 15, 30 and 45 kg ha$^{-1}$), sesamum variety RT-127 at S.K.N. College of Agriculture, Jobner in Rajasthan during kharif 2009. The experiment consisting of results indicated that application of sulphur @ 30 kg ha$^{-1}$, remaining at par with 45 kg ha$^{-1}$, significantly enhanced the growth, yield attributing characters and yield of sesamum. It increased the seed and stalk yield by margin of 30.7 and 28.4 per cent over control.

### 2.1.2 EFFECT OF BORON ON GROWTH, YIELD ATTRIBUTES AND YIELD

Agasimani et al. (1993) conducted a field experiment on groundnut during the kharif season of 1989 at Dharwad, Karnataka. The experimental soil contains 100 kg S and 16 kg B per hectare. Groundnut was treated with sulphur @ 0, 10 and 20 kg ha$^{-1}$ and boron @ 0, 2.5 and 5.0 kg ha$^{-1}$. Application of 2.5 kg B ha$^{-1}$ significantly increased the pod yield.

Pradhan and Sarkar (1993) found that rapeseed and mustard responded well to sulphur and boron fertilization in Terai soils of West Bengal. Application of sulphur @ 20 kg ha$^{-1}$ and boron @ 1 kg ha$^{-1}$ significantly increased plant height and leaf area indices at flowering. The yield attributing characters and grain yield were also improved with sulphur and boron treatments.

Sundarsan and Ramaswami (1993) conducted a field experiment on groundnut in sandy clay loam soils. Application of borax @ 5.0 kg ha$^{-1}$ as soil application produced 1571 kg ha$^{-1}$ pod yield, while application of 20 kg ZnSO$_4$ ha$^{-1}$ and 2.5 kg borax ha$^{-1}$ + foliar application of 0.5 per cent ZnSO$_4$ at 40 days after sowing + 0.24 per cent borax at 50 DAS produced significantly the highest seed yield of 1780 kg ha$^{-1}$.

Mahajan et al. (1994) found that boron supplied through boronated superphosphate @ 0.5 kg ha$^{-1}$ and foliar spray @ 0.5 ppm B, significantly increased the haulm yield of groundnut and also increased the pod yield.
Ghulaxe (1995) conducted a field experiment during 1991-92 at Akola, Maharashtra on groundnut Cv. TG-24. The application of 5 kg borax ha$^{-1}$ and 5 kg borax + 500 kg gypsum ha$^{-1}$ increased the dry pod yield and was found the highest with gypsum + boron.

Ramirez and Linares (1995) reported that sesame was exposed to 6.25-750 μg B litre$^{-1}$. Dry matter production of leaves, stems and roots were severely decreased when B in the leaf tissue was below 21 μg g$^{-1}$.

Subbaiah and Mittra (1996) reported that application of Zn and B along with recommended NPK dose increased the seed yield of mustard by 20 and 18 per cent in the first year and by 49 and 47 per cent in the second year, respectively over NPK alone. The increase in seed yield was associated with the increase in seliquae per plant and seeds per seliquae of mustard.

Talashikkar and Chavan (1996) observed that yield of groundnut enhanced significantly with the addition of borax @ 0.5 ha$^{-1}$. The maximum pod (2830 kg ha$^{-1}$) and haulm (4520 kg ha$^{-1}$) yields were recorded in the treatment receiving boron through boronated superphosphate along with application of FYM, N and P.

Lourduraj et al. (1997) while working with field experiment for three consecutive seasons during summer 1990, 1991 and 1992 revealed that groundnut yield and monetary returns were increased by application of iron, zinc, boron and gypsum. Application of 5 kg borax ha$^{-1}$ + 25 kg ZnSO$_4$ ha$^{-1}$ maximized the groundnut yield.

Patra (1998) revealed that application of 2.0 and 4.0 kg B ha$^{-1}$ produced 3.1 and 2.8 t soybean ha$^{-1}$, respectively, which were significantly higher than the control.

Hemantarajan et al. (2000) found the plants treated @ 100 ppm it appears that foliar applied B @ 50 ppm is the threshold level for obtaining optimum seed yield in Glycine max L. In untreated plants, the weight of seeds per plant was remarkably low as compared to treated plants.

Deasarker et al. (2001) conducted an experiment with soybean, was given 2, 4 and 6 kg B ha$^{-1}$. 2 kg B ha$^{-1}$ was the best among the boron treatment for increasing row seed yield.

Malewar et al. (2001) conducted a field experiment on mustard Cv. Pusa bold. The increase in stover yield due to application of borax @ 5.0 and 10 kg ha$^{-1}$ was 9.47 and 14.41 per cent and seed yield was 6.54 and 10.21 per cent, respectively.
Bagewadi et al. (2003) conducted a field experiment during the summer and Kharif seasons of 1999-2000 on groundnut Cv. JL-24 at Bangalore, Karnataka. They reported that the number of pods per plant and number of filled pods per plant increased with application of boron.

Liu et al. (2003) studied the effects of Mo and B, alone or in combination, on seed quality and growth of soybean in pot cultivars Zhechun 3, Zhechun 2, and 3811. Application of Mo and/or B increased the content of protein, in dispensable amino acids, total amino-acids (excluding proline), N, P, K and decrease the content of Ca and oil.

Rana et al. (2005) observed that 0.2% spray of borax recorded significantly higher branches plant$^{-1}$, siliqua plant$^{-1}$, seeds siliqua$^{-1}$, seed yield and biological yield of mustard over control during rabi season on sandy loam soils of IARI, New Delhi.

A field experiment was conducted in Maharashtra, India, during the rabi season of 2003-04 to assess the role of zinc and boron in the improvement of growth and yield of sunflower cv. Morden. Result showed that, borax at 60 kg ha$^{-1}$ brought significantly higher values than the control in terms of growth, yield contributing characters and seed yield. (Patil et al., 2006).

Meena et al. (2007) a review of secondary and micronutrients for groundnut, and reported that sulphur is secondary nutrient influencing the groundnut productivity preferably in addition to N, P, and K. In red loamy soils of Coimbatore, application of ZnSO$_4$ @ 20 kg ha$^{-1}$ plus 0.5 % foliar spray along with borax @ 25 kg ha$^{-1}$ plus 0.25 % foliar spray recorded the highest pod.

Significantly higher number of seeds capitulum$^{-1}$, seed yield and stover yield was obtained with application of 1.50 boron kg ha$^{-1}$ which was on par with application of 0.75 boron kg ha$^{-1}$during spring season on sunflower at Indian Agricultural Research Institute, New Delhi (Shekawath et al., 2008).

Sinha et al. (2008) conducted a field experiment at Departmental Research Farm, BAU, Ranchi to evaluate the effect of graded levels of boron with or without lime on groundnut. The treatments include four levels of B i.e. 0, 0.5, 1.0 and 1.5 kg ha$^{-1}$ and two levels of lime i.e. 0 and 3 q ha$^{-1}$ in furrow at the time of sowing. The results indicated that application of B @ 1 kg ha$^{-1}$ increased the pod yield of groundnut significantly, which was at par with 1.5 kg B ha$^{-1}$.The yield increase was to the tune of 33.7 and 36.6 per cent for 1.0 and 1.5 kg B ha$^{-1}$ over no B application,
respectively.

Srinivasan et al. (2008) studied groundnut (cv. VRI 2) yield, dry matter production and nodule number as influenced by yield, dry matter production, and number of nodules increased with the increase in B rate up to 15 kg ha⁻¹.

Amery et al. (2011) conducted an experiment on effect of boron foliar application on reproduction of sunflower and revealed that application of boron @ 250 mg L⁻¹ have shown significantly increased leaf area index and dry matter yield during spring season on sandy loam soil in Iraq.

Devi et al. (2011) reported that application of boron @ 1.5 kg ha⁻¹ recorded significantly higher branches plant⁻¹, pods plant⁻¹, seed yield and stover yield over control, 0.5, 1.0, 2.0 during kharif season in soyabean on sandy loam soils of Imphal.

Nandini et al. (2012) reported that soil application of boron @ 1.5 kg ha⁻¹ recorded significantly higher pods per plant (61), and seed yield (1831 kg ha⁻¹) of soybean as compared to control.

Ansari et al. (2013) conducted an experiment to study the efficacy of boron sources on productivity, profitability and energy use efficiency of groundnut and revealed that application of boron through solubor @ 5 kg ha⁻¹ significantly increased plant height and grain yield of sesame over different sources of boron like borax, chemibor, agricol, borosol during kharif season in New Delhi.

Jeena et al. (2013) conducted an experiment at Onattukara Agro ecological Zone, Kerala revealed that application of 2.5 kg B ha⁻¹ reported significantly higher no. of capsules plant⁻¹ and seed yield of sesame over control, 5, 7.5 kg B ha⁻¹.

An experiment was conducted on effect of phosphorus, calcium and boron on the growth and yield of groundnut and revealed that application of 2.5 kg boron ha⁻¹ significantly increased plant height and leaf area index over application of 2.0 kg boron ha⁻¹ on silty loam soil of Bangladesh (Kabir et al. 2013).

Sudeshan and Saren (2013) revealed that significantly increased plant height, dry matter yield and grain yield of winter niger with application of boron as 2% borax spray at branching and it was on par with application of 0.2% borax spray at branching and flowering during kharif season in West Bengal.

Gowthami and Rao (2014) revealed that significant increase in leaf area index crop growth rate and relative growth rate was observed with application of boron @ 50 ppm as foliar spray of soybean on clay loam soils in Andhra Pradesh.
The results of the experiment conducted by Tahir et al. (2014) with different levels of boron *i.e.* 2, 4, 6, 8, 10 kg B ha\(^{-1}\) recorded an increasing trend in plant height upto 6 kg B ha\(^{-1}\) beyond that plant height have shown deceasing trend. Application of 6 kg B ha\(^{-1}\) recorded significantly higher plant height of sunflower on sandy loam soils during *spring* season in Pakistan.

Naiknaware et al. (2015) reported that four levels of boron viz., no boron (B\(_0\)), 4 kg B ha\(^{-1}\) (B\(_1\)), 8 kg B ha\(^{-1}\) (B\(_2\)) and 12 kg B ha\(^{-1}\) (B\(_3\)) and three levels of elemental sulphur viz., no sulphur (S\(_0\)), 20 kg S ha\(^{-1}\) (S\(_1\)) and 40 kg S ha\(^{-1}\) (S\(_2\)). The results of the experiment revealed that the groundnut crop fertilized with 8 kg boron showed remarkably increased plant growth parameters viz., No. of pegs per plant (43.88) and No. of nodules (102.00) at 50-55 DAS and yield attributes viz., numbers of pods per plant (10.83) and kernel yield (1214 kg ha\(^{-1}\)).

### 2.1.3 COMBINED EFFECT OF SULPHUR AND BORON ON GROWTH, YIELD ATTRIBUTES AND YIELD

Singh et al. (2006) field experiments were conducted during the 2001-03 kharif season in Jharkhand, India, on soyabean cv. Birsa to determine the optimum level of S (0, 20, 40 and 60 kg ha\(^{-1}\)) and B (0, 0.5, 1.0 and 2.0 kg ha\(^{-1}\)) for soyabean grown in an acidic upland soil. Maximum seed yield of soyabean was obtained with 60 kg S + 2.0 kg B ha\(^{-1}\).

Combined application of 100 % recommended dose of fertilizer (40: 20: 20: 30 NPKS ha\(^{-1}\)) along with application of farmyard manure 2.5 t ha\(^{-1}\) and micronutrients recorded significantly higher seed yield in sesame during *kharif* season in Jhansi (Yadav et al., 2009).

Mathew et al. (2013) it has been observed that sulphur and boron play a synergistic role in improving the grain yield and yield attributes of sesameum.

Mallick and Raj (2015) reported that successive increase in P, S and B levels increased yield attributes and seed yield of yellow sarson crop. Application of boron @ 1 kg B ha\(^{-1}\) also resulted into a significant increase in different growth attributes like plant height, dry matter accumulation, LAI and CGR over control. Application of B (1 kg ha\(^{-1}\)) had also resulted marked increase in siliquae plant\(^{-1}\) and seeds siliqua\(^{-1}\) compared with the control.
2.2 QUALITY PARAMETERS

2.2.1 EFFECT OF SULPHUR ON QUALITY PARAMETERS

Nagavani et al. (2001) reported that application of sulphur at 60 kg ha\(^{-1}\) significantly increased oil content over control and 20 kg S ha\(^{-1}\) and 40 kg S ha\(^{-1}\) of sesame on sandy clay loam soils in Tirupati.

Dayanand et al. (2002) conducted a field experiment to study the effects of sulphur on nutrient uptake and food value of sesame (Sesamum indicum). They reported that protein and oil content of sesame significantly increased upto 60 kg S ha\(^{-1}\).

Meena et al. (2007) reported that the application of gypsum @ 1.5 t ha\(^{-1}\) at flowering was found to be most effective in increasing oil content.

A field experiment was carried out at Sardarkrushinagar (Gujarat) in loamy sand soil. From the results, Patel et al. (2009) reported that maximum oil content in sesamum was recorded with 30 kg gypsum ha\(^{-1}\) which was at par with that of 20 kg ha\(^{-1}\).

An experiment was conducted on sesame (Sesamum indicum L.) in clay loam soils of Jabalpur during kharif revealed that application of 30 kg S ha\(^{-1}\) reported significantly higher oil per cent and oil yield which was on par with application of 15 kg S ha\(^{-1}\) with different sources of sulphur (Deshmukh et al., 2010).

Jadav et al. (2010) obtained significantly higher oil content oil yield and protein content with application of 40 kg S ha\(^{-1}\) which was statistically on par with application of 20 kg S ha\(^{-1}\) of sesame on sandy loam soil during kharif season at Junagadh, Gujarat.

Vaghani et al. (2010) reported that application of 45 kg S ha\(^{-1}\) in sesame (Sesamum indicum L.) recorded significantly higher oil content and protein content over control and 20 kg S ha\(^{-1}\) of sesame on medium black soils during kharif season at Junagadh.

De et al. (2013) revealed that oil percentage and oil yield were significantly increased up to 40 kg S ha\(^{-1}\) over 20 kg S ha\(^{-1}\).

Mathew et al. (2013) revealed that sesamum responded significantly to the application of sulphur up to 30 kg ha\(^{-1}\) for shelling per cent at Onattukara (Kerala).

A pot experiment was conducted by Sisodiya (2014) at College of Agriculture, Junagadh agricultural university, Junagadh to study the response of groundnut
(Arachis hypogaea L.) to sources and levels of sulphur fertilization in medium black calcareous soil. Results revealed that application of sulphur @ 20 mg kg\(^{-1}\) gave significantly higher oil content.

Tahir et al. (2014) revealed that oil content and protein content were increased significantly with application of 50 kg S ha\(^{-1}\) over control, 10, 20, 30 and 40 kg S ha\(^{-1}\) of sesame in during summer season on sandy clay loam soils in Pakistan.

An experiment was conducted by Thentu et al. (2014) at Agriculture College, Nagpur during summer season of 2011-2012. They revealed that oil content was significantly more due to application of 40 kg S ha\(^{-1}\) over control and 10 kg S ha\(^{-1}\).

Tulasi et al. (2014) conducted an experiment on quality of summer sesame as influenced by fertilizer and sulphur levels and reported that application of 40 kg S ha\(^{-1}\) increased oil content over control, 10, 50 kg S ha\(^{-1}\) which was at par with application of 20 and 30 kg S ha\(^{-1}\) during summer season at Nagpur.

### 2.2.2 EFFECT OF BORON ON QUALITY PARAMETERS

Wani et al. (1998) revealed that application of B enriched superphosphate in groundnut at 100 kg P\(_2\)O\(_5\) ha\(^{-1}\) had protein content of 28.81 per cent and oil content of 48.67 per cent compared with 25.32 per cent and 45.37 per cent, respectively, without P.

Chandel et al. (1989) evaluated that application of 2.0 kg B which produced the highest oil content in soybean (21.19 %) while 4.0 kg B ha\(^{-1}\) produced the highest oil yield (492 kg ha\(^{-1}\)).

Ramamoorthy and Sudarsan (1992) while working on a field trial at Coimbatore, Tamilnadu, with groundnut Cv. Co-2 applied 2.5 or 5.0 kg borax as a foliar spray at 30 days after sowing significantly increased the seed protein and oil percentages.

Agasimani et al. (1993) applied boron @ 0, 2.5 and 5.0 kg B ha\(^{-1}\) and sulphur @ 0, 10 and 20 kg ha\(^{-1}\) in groundnut. They found that significantly higher oil content (48.83 %) was recorded with application of B @ 5 kg ha\(^{-1}\) and S @ 10 kg ha\(^{-1}\).

Mahajan et al. (1994) found that application of B @ 0.5 kg ha\(^{-1}\) through boronated superphosphate as soil application and 0.5, 1.0 and 1.5 kg ha\(^{-1}\) through borax and total spray of 0.5 ppm B. All the treatments significantly increased the oil content in kernel compared with the control.
Sindoni et al. (1994) grew *Sesamum indicum* in Hoagland No. 2 nutrient solution supplemented with 0.05 mg B liter$^{-1}$ or throughout the growth or until 20-30 or 40-day-old when B was either reduced to 0.25 mg l$^{-1}$ or eliminated completely. Elimination of B at all ages reduced root and shoot dry weight but reduction of B supplementation significantly reduced dry weight only at 30 day.

Subbaiah and Mittra (1996) reported that application of B along with recommended NPK dose increased the 100 seed weight and significantly increased the oil contents in mustard.

Tamak et al. (1997) observed that application of 0.2 per cent borax as foliar spray at 50 per cent flowering stage significantly increased the 100 seed weight and oil content of sunflower.

Chakraborty and Das (2000) deal with a field trial in West Bengal, growing rape and was given with 0, 30 or 60 kg S ha$^{-1}$ and 0, 2.0 or 3.0 kg B ha$^{-1}$. Quality parameters like oil and protein contents were significantly increased by the application of sulphur and boron.

Nasef et al. (2006) field experiment were carried out in Ismailia Agriculture Station, Egypt during summer season to evaluate the influence of foliar application of boron with rhizobium inoculation on oil and protein content of groundnut. The highest oil (47.89%) and protein (33.40%) percentage of peanut seed were attained when the highest level of boron (300 ppm) was used followed by 200 ppm and 100 ppm in decreasing order.

Venkatesh et al. (2006) study the response of groundnut to sulphur, boron and FYM levels. Boron application @ 3 kg ha$^{-1}$ was beneficial for getting maximum protein content. The maximum oil and protein content was observed by the application of 40 kg S ha$^{-1}$ + 3 kg B ha$^{-1}$ + 5 t FYM ha$^{-1}$.

Adkine et al. (2011) reported that the maximum and significant increase in soyabean test weight, protein yield ha$^{-1}$, oil yield ha$^{-1}$ and GMR, NMR were observed with soil application of RDF + boron @ 1 kg ha$^{-1}$ at the time of sowing.

Rashid et al. (2012) reported that soil application of boron @ 1.5 kg ha$^{-1}$ has recorded significantly higher oil content (40.77 %) of mustard as compared to control.

Jeena et al. (2013) conducted an experiment at Onattukara Agro ecological Zone, Kerala revealed that application of boron reported increase in oil content and grain protein of sesame but it was not significantly differing between treatments *i.e.* control, 2.5 kg B ha$^{-1}$, 5.0 kg B ha$^{-1}$ and 7.5 kg B ha$^{-1}$.
Sudeshan and Saren (2013) reported that application of boron as 2% borax spray at branching and flowering significantly increased oil content and it was on par with application of 0.2% borax spray at branching (40.71%) of winter niger during kharif season in West Bengal.

Tahir et al. (2014) revealed that application of boron @ 6.0 kg ha\(^{-1}\) recorded significantly superior oil content and protein content over application of 2, 4, 8, 10 kg boron ha\(^{-1}\) of sunflower during spring on clay loam soil in Faisalabad.

Naiknaware et al. (2015) reported that the application of boron 8 kg ha\(^{-1}\) increased protein and oil contain in groundnut as compared to controlled treatment. Because they plays important role in synthesis of essential amino acids like cysteine, methionine, and certain vitamin like biotine, thymine, Vit. B\(_1\) as well as the formation of ferodoxin and iron containing plants. Protein that act as electron carrier in photosynthetic process. Which required for production of oil.

**2.2.3 COMBINED EFFECT OF SULPHUR AND BORON ON QUALITY PARAMETERS**

Karthikeyan and Shukla (2008) study the effect of sulphur and boron on the quality attributes of sesame. It had been found that the highest value of grain protein content of sesame was significantly influenced by the interaction between different levels of sulphur and boron.

Application of farmyard manure 2.5 t ha\(^{-1}\) along with recommended dose of fertilizer (120-40-20 kg N, P, K ha\(^{-1}\)) and 40-25-1 kg S, ZnSO\(_4\), B ha\(^{-1}\) with Azatobacter seed treatment recorded highest oil content (40%) in mustard during rabi season of Uttarakandh (Tripathy et al., 2011).

**2.3 CONTENT AND UPTAKE OF NUTRIENTS**

**2.3.1 EFFECT OF SULPHUR ON CONTENT AND UPTAKE OF NUTRIENTS**

Vaijapuri et al. (2003) evaluate the effects of sulphur (0, 15, 30 and 45 kg ha\(^{-1}\)) and organic amendments (10 t ha\(^{-1}\) each of farmyard manure, poultry manure and press mud) on the nutrient uptake of sesame cv. TMV 3. They found that application of 45 kg S ha\(^{-1}\) gave the best result in terms nitrogen, phosphorus, potassium and sulphur uptake.
Maragatham et al. (2006) observed the effects of sulphur at 0, 20, 40, 60 and 80 kg ha\(^{-1}\) applied alone or in combination with farmyard manure on seed yield as well as S uptake of sesame. Application of sulphur at 40 kg ha\(^{-1}\) resulted in highest S uptake by plants.

Singh and Singh (2007) conducted an experiment on effect of sources and levels of sulphur on nutrient uptake by linseed and reported that application of 60 kg S ha\(^{-1}\) significantly increased total N, P and S uptake on alluvial soils in Uttar Pradesh.

Chaurasia et al. (2009) compared the effect of different levels of sulphur viz., 0, 10, 20, 30 and 40 kg ha\(^{-1}\) on soybean responded significantly in terms of higher uptake of N, P, K and S.

Jadav et al. (2010) revealed that application of sulphur 40 kg S ha\(^{-1}\) increased uptake of S and K increased nutrient uptake by sesame seed (30.26, 5.29, 5.46 and 7.13 kg ha\(^{-1}\) N, P, K and S) and stover (15.10, 2.69, 6.08 and 12.82 kg ha\(^{-1}\) N, P, K and S).

An experiment was conducted on effect of sources and spacing on the growth, yield and quality of Sunflower during spring season on sandy loam soils of in Uttar Pradesh revealed that application of 30 kg S ha\(^{-1}\) increased seed sulphur uptake and sulphur use efficiency (Kumar et al. 2011).

A field experiment was carried out at Kashmir valley during temperate conditions. From the results, Najar et al. (2011) reported that application of 40 kg S ha\(^{-1}\) recorded the highest total N, P, K and S nutrients uptake by soybean over rest of the treatments.

A field experiment was conducted at Sriniketan, West Bengal, during summers to evaluate the effects of different sources (phosphogypsum and magnesium sulphate) on S uptake of sesamum (cv. Rama) on red and lateritic soils. The highest total S uptake was observed at all levels of S when magnesium sulphate was the source, followed by phosphogypsum (Patiet et al. 2011).

Jena and Kabi (2012) reported that application of bentonite sulphur and gypsum significantly increased the nutrient uptake by crop. Among the different sources bentonite sulphur was found to be best source of S because of high concentration, slow release and minimum leaching loss.

A pot experiment was conducted by Parakhia (2014) at College of Agriculture, Junagadh agricultural university, Junagadh to study the varietal response of soybean [glycine max (l) merrill] to sulphur in medium black calcareous soil.
Results revealed that application of sulphur @ 15 mg kg\(^{-1}\) significantly increase the content and uptake of N, P, K and S by soybean.

A pot experiment was conducted by Sisodiya (2014) at College of Agriculture, Junagadh agricultural university, Junagadh to study the response of groundnut (\textit{Arachis hypogaea} L.) to sources and levels of sulphur fertilization in medium black calcareous soil. Results revealed that application of sulphur @ 20 mg kg\(^{-1}\) gave significantly higher content and uptake of (N, P, K, S, Fe, Mn, Zn and Cu) by groundnut.

2.3.2 EFFECT OF BORON ON CONTENT AND UPTAKE OF NUTRIENTS

Luo \textit{et al.} (1990) found that application of sodium borate @ 7.5 kg ha\(^{-1}\) to the soil increased boron content of groundnut at 4 different growth stages (seedling, flowering, pod setting and harvesting). The application of B fertilizer promoted uptake of N, P, and K.

Shinde \textit{et al.} (1990) while working in a field trials during 6 years (1979-85) with groundnut grown on a sandy loam soil having 0.325 ppm B, showed that application of 5 kg borax ha\(^{-1}\) each year was more effective than application once in 2 or 3 years in increasing boron uptake.

In a field assay on calcareous soil, application of boronated superphosphate gave the highest uptake of N, P and B by sunflower crop. (Ateeque and Malewar, 1992).

Mohammed \textit{et al.} (1993) found that application of boronated superphosphate (containing 0.18 % B) showed the highest concentration of N (0.97 %), P (0.31 %) and B (16.0 ppm) in dry matter of sunflower.

Mahajan \textit{et al.} (1994) observed that the nitrogen content in kernel of groundnut increased with application of B compared with control. The uptake of N by kernel significantly increased under soil and foliar application of B @ 0.5 kg ha\(^{-1}\) through boronated superphosphate and foliar spray of 0.5 ppm B compared with the control. The highest N uptake (127.4 kg ha\(^{-1}\)) was found with B @ 0.5 kg ha\(^{-1}\) as boronated superphosphate followed by foliar spray (96.1 kg ha\(^{-1}\) of 0.5 ppm B. The phosphorus content in kernel did not vary due to treatments. However its uptake was significantly higher (11.7 kg ha\(^{-1}\)) under B @ 0.5 kg ha\(^{-1}\) as boronated superphosphate.
Kumar et al. (1996) reported that the concentration of B in groundnut pod and haulm was significantly influenced by the different source of boron used in the investigation. The highest B concentration was recorded in groundnut pod as well as in haulm when boron was applied as boric acid. Boron uptake by groundnut pod with boric acid (23.7 g ha\(^{-1}\)) was also found significantly higher than that with borax (18.8 g ha\(^{-1}\)). The B uptake by groundnut pod, haulm as well as total uptake was found the highest at 3 kg B ha\(^{-1}\).

Reinbott et al. (1997) found that foliar application of 2.24 kg B ha\(^{-1}\) on soybean increased main stem leaf B content from 47 to 248 µg g\(^{-1}\) and in a separate experiment, foliar application of 1.12 kg B ha\(^{-1}\) to soybean increased leaf B content by over 50 µg g\(^{-1}\). In other field experiment, foliar applications of B @ 0.9 kg ha\(^{-1}\) increased leaf B content in both main stem and branch leaves in main stem leaves.

Sharma et al. (1999) examined the role of organic manure and boron on availability of boron. In a green house experiment application of 0.5 mg B kg\(^{-1}\) soil increased the boron content in plant and accumulation in sunflower.

Shanke et al. (2003) studied the response of groundnut to boron and molybdenum in relation to nutrient content and uptake. The results showed that the boron through foliar spray (0.5%) gave highest the concentrations and uptake of B.

Bhagiya et al. (2005) studied the effect of B and Mo on nutrient uptake by groundnut. The application of B @ 4.0 kg ha\(^{-1}\) significantly increased the N, P, K and B uptake by pod and N and B uptake by haulm.

Rana et al. (2005) conducted a field experiment during the winter seasons of 2001-03 at New Delhi. They reported that the foliar application of boron @ 0.2 percent at 50 percent flowering recorded marked improvement in uptake of B (14.3 percent) in rainfed Indian mustard.

Total nutrient uptake i.e. N, P, K and S uptake was increased with application of boron over control during spring season on sunflower at Indian Agricultural Research Institute, New Delhi, Shekawath and Shivay (2008).

Jeena et al. (2013) conducted an experiment on sesame at Onattukara Agro ecological zone, Kerala revealed that application of boron improved availability of N, P, K, S and boron availability in soil. Highest nutrient uptake was recorded with application of 7.5 kg B ha\(^{-1}\).
Hamideldin and Hussein (2014) study that the sesame plants were sprayed with different concentrations of boron solution at 20, 30 and 40 ppm at different stages of plant growth (1, 2 and 3 months). Comparing the treated plants with untreated controls, the obtained results showed that spraying sesame plants with boron (B) solutions improves their growth and yields. The highest oil viscosity was recorded at a boron concentration of 30 ppm. Fatty acids were decreased by the effect of boron spray. Sesame plants with boron decreased the Fe, K, Mg and P contents, whereas the lowest concentration of boron (20 ppm) increased Ca and the highest concentration (40 ppm) increased Cl and Na.

Mallick and Raj (2015) reported that successive increase in P, S and B levels increased yield attributes and seed yield of yellow sarson crop. Boron application induced marked increase in the uptake of P and S. This increased in P and S uptake could be credited to variation in the availability of these nutrients in the soil and partly due to priming effect of one nutrient on the other with P, S and B application up to 60 kg P₂O₅/ha, 20 kg S/ha and 1 kg B/ha, respectively.

2.3.3 COMBINED EFFECT OF SULPHUR AND BORON ON CONTENT AND UPTAKE OF NUTRIENTS

An experiment was to study interaction effect of sulphur and boron on yield, nutrient uptake and quality characters of soybean (Glycine max L.) grown in acidic upland soil. They reported that the total S uptake at 0 and 60 kg S ha⁻¹ was 10.27 and 16.72 kg ha⁻¹, respectively, whereas total B uptake at 0 and 2.0 kg B ha⁻¹ was 98.58 and 198.72 kg ha⁻¹, respectively (Singh et al., 2006).

Mathew and George (2012) conducted two field experiments were carried out within four levels each of sulphur and boron in sesamum having a total of sixteen treatments combinations. Application of these nutrients resulted in improving the availability of P, K, Mg, S, B, Fe, Mn, and Zn.

Ullasa et al. (2014) revealed that application of farmyard manure 5 t ha⁻¹ increased nutrient uptake by plant (N, P, K, S, Zn and B @ 102 kg ha⁻¹, 26.1 kg ha⁻¹, 114 kg ha⁻¹, 12.1 kg ha⁻¹, 712 g ha⁻¹, 294 g ha⁻¹) over control in sunflower during kharif on medium black soil in Bengaluru.
2.4 POST HARVEST SOIL STATUS OF AVAILABLE NUTRIENTS

2.4.1 EFFECT OF SULPHUR ON POST HARVEST SOIL STATUS OF AVAILABLE NUTRIENTS

According to Vijaypriya et al. (2005) application of gypsum @ 30 kg ha\(^{-1}\) in presence of Brady rhizobium inoculation significantly increase the availability of sulphur in clay loam soil.

Singh and Maan (2007) studied the effect of sulphur (0, 20, 40 and 60 kg ha\(^{-1}\)) on groundnut (Arachis hypogaea L). From the groundnut growing fields, available and total S contents in the soil varied from 142.0 to 232.0 kg ha\(^{-1}\) and 4.0 to 26.0 mg kg\(^{-1}\). The use efficiency of S with increase in the level of S, and maximum S use efficiency was recorded at lower levels of S application.

Chaurasia et al. (2009) reported that increased the availability of N, P, K and S in soil up to 40 kg S ha\(^{-1}\) through single super phosphate.

Gupta and Jain (2009) conducted trial to study the direct effect of sulphur (0, 15, 30 and 45 kg ha\(^{-1}\)) on groundnut (Arachis hypogaea L). The results revealed that S fertilization up to 45 kg ha\(^{-1}\) significantly increased apparent S recovery in groundnut-wheat system increased with the increasing level of sulphur up to 45 kg ha\(^{-1}\) while physiological efficiency was maximum of S @ 15 kg ha\(^{-1}\). Continuous sulphur application increased the available sulphur status in soil when S applied @ 30 and 45 kg ha\(^{-1}\).

Ramdevputara et al. (2010) revealed that the available potassium and sulphur status after harvesting of crop were significantly affected due to different treatments. During studied the effect of sulphur application on soil fertility under rainfed agriculture.

Vaghani et al. (2010) reported that the availability of N and K\(_2\)O content in soil is increasing and decrease in P\(_2\)O availability with increase in sulphur level but there was no significant difference in availability of N, P\(_2\)O\(_5\) and K\(_2\)O but availability of sulphur increased with 40 kg S ha\(^{-1}\) in sesame.

Vidyathi et al. (2011) reported that application of sulphur along with organic manure resulted significantly higher uptake of N, P, K and other micro nutrient and improve soil fertility and productivity in groundnut cropping system in kharif and rabi seasons.

A field experiment was conducted by Mathew et al. (2013) at Onattukara (Kerala) to study the effect of varying levels of sulphur (0, 7.5, 15 and 30 kg ha\(^{-1}\)) on
nutrient uptake of sesamum. The results revealed that sesamum responded significantly to the application of sulphur up to 30 kg ha\(^{-1}\) for increased availability of soil nutrients including sulphur and boron.

### 2.4.2 EFFECT OF BORON ON POST HARVEST SOIL STATUS OF AVAILABLE NUTRIENTS

Asokan and Raj (1976) in case of bunch groundnut observed that hot water soluble (HWS)-B content of soil increased with increase in applied doses of boron. The available boron content decreased with time and more rapidly during first 40 days presumably due to rapid absorption by plant in the active period of growth and partly due to its fixation.

Shinde and Kale (1985) while working with groundnut, reported that available B content of soil at harvest was significantly higher in pods where B was applied. Amongst 5 and 10 kg borax ha\(^{-1}\) treatments, the latter application resulted in significantly higher available B at harvest.

Golakiya (1992) conducted a pot experiment on a calcareous clay soil with groundnut. Available B in soil decreased from 0.76 ppm to 0.65 ppm with application of CaCO\(_3\) 30 per cent and application of 2.0 ppm B.

Pabitra and Haider (1996) found that application of B increased the content of HWS - B in soil. The application of B could maintain 11.5 and 12.5 per cent of the added boron as In @ 5 kg ha\(^{-1}\) and 10 kg ha\(^{-1}\), respectively, in HWS-B from 10 day incubation in the absence of liming. The results thus showed a beneficial effects of liming on B recovery in the given soil.

Sharma et al. (1999) examine the role of organic manure and boron on availability of boron in a greenhouse experiment. Application of 5 mg B kg\(^{-1}\) soil significantly increased the content hot water soluble B in the soil after harvesting of sunflower.

Singh et al. (2005) reported that B application of 1 and 2 kg ha\(^{-1}\) buildup of available B in the soil after harvesting of groundnut 0.53 and 0.59 mg kg\(^{-1}\), respectively.

### 2.4.3 COMBINED EFFECT OF SULPHUR AND BORON ON POST HARVEST SOIL STATUS OF AVAILABLE NUTRIENTS

Maragatham et al. (2006) observed the effects of sulphur at 0, 20, 40, 60 and 80 kg ha\(^{-1}\) applied alone or in combination with farmyard manure on seed yield as well as
S uptake of Sesame. Application of sulphur at 40 kg ha\(^{-1}\) resulted in highest S uptake by plants.

Mathew et al. (2013) study the effect of sulphur (S) and boron (B) on the productivity of sesame (*Sesamum indicum* L.) in an Entisol of Kerala, a field experiment was laid out in a factorial RBD with 4 levels each of sulphur (0, 7.5, 15.0 and 30 kg S ha\(^{-1}\)) and boron (0, 2.5, 5.0 and 7.5 kg B ha\(^{-1}\)). Results showed that S and B acted synergistically in the available nutrient status was also significantly improved by the application of these nutrients.

Ullasa et al. (2014) conducted an experiment on effect of application of farmyard manure, fertilizer levels and different plant population levels significantly increase seed yield, nutrient uptake by sunflower and final nutrient status of the soil.