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Effect of Sulphur Nutrition in Groundnut: A Review

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ABSTRACT

Suphur plays a vital role in the development of seed and improving oil quality. Groundnut is rich in oils and protein hence sulphur requirement for this crop is substantially high. Sulphur levels from 20 to 70 kg ha^{-1} were tried in groundnut among which higher level of sulphur @ 60 kg ha^{-1} has recorded taller plants, higher leaf area index, dry matter production pod number, pod yield and oil quality in groundnut. Gypsum application at 400 kg ha^{-1} (200 kg as basal and remaining 200 kg ha^{-1} during earthing up) has increased the pod yield, oil content and oil yield in groundnut.

Key words: Groundnut, Gypsum, Oil yield, Pod yield, Sulphur.

Sulphur is increasingly being recognised as the fourth major nutrient after nitrogen, phosphorus and potassium (Tandon and Messick, 2002). It is the master nutrient for oilseed production as each unit of sulphur fertilizer generates 3-5 units of edible oil. In oilseeds sulphur plays a vital role in the development of seed and improving the quality (Naser *et al.,* 2013). Sulphur helps in the synthesis of cysteine, methionine, chlorophyll, vitamins (B, biotin and thiamine), metabolism of carbohydrates, oil content, protein content and also associated with growth and metabolism, especially by its effect on the proteolytic enzymes (Najar *et al*., 2011). Sulphur deficiency results in poor flowering, fruiting, cupping of leaves, reddening of stems, petiole and stunted growth. Since groundnut is rich both in oils and protein, requirement of sulphur for this crop is substantial high. Sulphur improves the chlorophyll, nodulation, increases the availability of other nutrients (Singh 2007).

Effect of sulphur on growth attributes of groundnut

Plant height

Battacharya *et al.* (1997) reported that application of S @ 20 kg ha^{-1} significantly increased the plant height, dry matter and nodulation in groundnut than control. Kadam *et al.* (2000) revealed that sulphur fertilization at 40 kg ha^{-1} recorded significantly higher plant height against control in groundnut.

Chauber *et al.* (2000) registered that application of S at 45 kg ha^{-1} through gypsum significantly gave higher plant height in groundnut. Kalaiyarasan *et al.* (2002) reported that growth parameters especially plant height increased significantly with increasing levels of sulphur in groundnut. Singh *et al.* (2003) observed that sulphur fertilization at 60 kg ha^{-1} registered significant improvement in plant height at 30, 60 and 90 DAS and at harvest stages over 20 and 40 kg S ha^{-1} and control in groundnut. Mandal *et al.* (2005) disclosed that application of gypsum at 400 kg ha^{-1} significantly recorded highest plant height (65.1 cm) and the lowest plant height in control (46.5 cm) in groundnut. Jat and Ahlawat (2009) disclosed that application of sulphur at 70 kg ha^{-1} significantly improved the plant height of groundnut over absolute control. Kannan *et al.* (2016) suggested that application of S through gypsum @ of 400 kg ha^{-1} in split mode *viz.,* 200 kg as basal and 200 kg as top dressing recorded highest plant height over control in groundnut. Nagesh Yadav *et al.* (2017) concluded that application of S @ 60 kg ha^{-1} through gypsum registered significant increase in plant height than other levels and sources in groundnut. Bairagi *et al.* (2017) reported that application of gypsum @ 500 kg ha^{-1} significantly increased the plant height of groundnut over control.

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Leaf area index

Kamalakannan *et al.* (2006) reported that application of 40 kg S ha^{-1} recorded the highest leaf area index in groundnut. Gashti *et al.* (2009) evaluated the effects of sulphur fertilizer sources and levels on growth indices of peanut (*Arachis hypogaea* L. *CV. NC2*) and results indicated that the higher LAI (6.6) were obtained with 90 kg S ha^{-1} in the form of gypsum. Piri *et al.* (2012) described that sulphur with its involvement in the metabolic process enhances the meristematic activity and thus causes higher apical growth with the expansion of photosynthetic surface.

Dry matter production

Bandopadhyay and Samui (2000) reported that application of S at 30 kg ha^{-1} significantly improved the haulm yields of groundnut over control. Kalaiyarasan *et al.* (2002) reported that dry matter production $plant^{-1}$ increased significantly with increasing levels of sulphur. Tripathi and Hazra, 2003 reported that application of gypsum @ 500 kg ha^{-1} gave

higher haulm yield in groundnut. Gupta and Jain (2007) registered that increasing levels of sulphur up to 45 kg ha^{-1} significantly increased the haulm yield by 28.4 per cent over control. Salke *et al.* (2011) revealed that application of gypsum @ 500 kg ha^{-1} increased the haulm yield in groundnut. Longkumer and Gohain (2012) observed that increasing levels of sulphur up to 40 kg ha^{-1} significantly improved the dry matter accumulation over lower levels and control in groundnut. Pinki Pancholi *et al.* (2017) disclosed that application of sulphur @ 60 kg ha^{-1} through gypsum significantly increased the haulm yield over control in groundnut.

Effect of sulphur on yield attributes of groundnut

Agasimani *et al.* (1993) observed that application of sulphur at 20 kg ha^{-1} gave significantly more number of pods $plant^{-1}$ and pod yield than control. Dimree *et al.* (1993) surmised that every increase in levels of S upto 45 kg ha^{-1} in groundnut produced significantly more number of pods $plant^{-1}$, kernels pod^{-1}, pod weight $plant^{-1}$, biomass production and shell yield over 15 and 30 kg ha^{-1} and control. Shivraj and Gowda (1993) documented that application of S @ 30 kg ha^{-1} gave significant increase in shelling percentage, 100-kernel weight, pod yield, haulm yield and oil yield of groundnut.

Kumpawat and Rathore (1994) observed significant increase in pod yield of groundnut with the application of sulphur upto 150 kg ha^{-1}. Tiwari *et al.* (1994) revealed that pod yield increased progressively with increasing levels of sulphur up to 100 kg ha^{-1} in groundnut. Singh and Choudhary (1996) concluded that application of sulphur at 50 kg ha^{-1} gave significantly higher number of pods/plant, pod yield and haulm yield of groundnut over control. Panda *et al.* (1997) registered that application of S @ 30 kg ha^{-1} in groundnut enhanced the pod yield significantly over control.

Sahu *et al.* (1999) divulged that application of S at 45 kg ha^{-1} significantly increased the pod yield, shelling percentage and uptake of S in rainfed groundnut. Adhikari *et al.* (2000) reported that application of gypsum at 400 kg ha^{-1} significantly increased number of pods $plant^{-1}$ and shelling per cent of groundnut. Dutta *et al.* (2000) noted significant increase in number of pegs per plant with the application of sulphur @ 60 kg ha^{-1} in groundnut. Bandopadhyay and Samui (2000) surmised that application of S at 30 kg ha^{-1} significantly improved the yield attributes *viz.,* pods $plant^{-1}$, kernels pod^{-1}, shelling percentage and 100-kernel weight as well as pod yield, kernel and haulm yields of groundnut over control.

Chauber *et al.* (2000) disclosed that application of S @ 45 kg ha^{-1} significantly increased the number of pods $plant^{-1}$, shelling percentage, 100-kernel weight and pod yield in groundnut. Kumaran (2001) also suggested that application of S through gypsum @ 400 kg ha^{-1} produced maximum number of seeds per pod in groundnut.

Kalaiyarasan *et al.* (2002) documented that growth parameters of groundnut *viz.* plant height and dry matter production $plant^{-1}$ increased significantly with increasing levels of sulphur. Maity *et al.* (2003) noted the highest yield attributes and pod yield of groundnut when the crop was applied with sulphur at 30 kg ha^{-1}. Prasad (2003) surmised that significant increase in biological yield was attained when sulphur was applied @ 40 kg ha^{-1} in groundnut. Kalaiyarasan *et al.* (2003) revealed that application of S at 45 kg ha^{-1} through gypsum significantly increased oil and protein content in groundnut kernel.

Singh *et al.* (2005) reported that application of S at 45 kg ha^{-1} significantly increased the pod yield of groundnut. Jamal *et al.* (2006) noted significant increase in number of pods per plant with application of sulphur @ 20 kg ha^{-1}. Singh and Mann (2007) observed that application of 40 kg S ha^{-1} and 5 kg Zn ha^{-1} significantly increased the pod yield of groundnut. Gupta and Jain (2007) surmised that application of S at 45 kg ha^{-1} significantly increased the mean pod yield of groundnut and haulm yield. Vagharia *et al.* (2007) revealed that application of S at 50 kg ha^{-1} increased the groundnut yield as well as the high benefit cost ratio. Kalaiyarasan *et al.* (2007) registered that application of S at 60 kg ha^{-1} significantly increased the yield attributes and pod yield of groundnut.

Patel *et al.* (2008) revealed that application of sulphur up to 40 kg ha^{-1} significantly increased the pod yield of groundnut. Tathe *et al.* (2008) disclosed that application of sulphur @ 120 kg ha^{-1} recorded significantly the highest dry pod yield, oil and protein content of groundnut. Krishna Murthy *et al.* (2009) registered that application of recommended dose of fertilizer + vermompost + gypsum recorded significantly higher pod yield in groundnut. Patel *et al.* (2009) concluded that sulphur fertilization at 40 kg ha^{-1} gave significantly higher number of pods per plant, shelling percentage, 100-kernels weight, weight of pods per plants.

Gunr *et al.* (2012) divulged that pod yield increased with the increasing levels of gypsum application in groundnut. Premanantharajah and Prapagar (2013) noted that application of S @ 75 kg ha^{-1} through elemental sulphur significantly increased the pod yield, protein and oil content of groundnut. Tejeswara Rao *et al.* (2013) concluded that application of sulphur of 45 kg ha^{-1} through gypsum recorded the highest number of filled pods per plant, 100 pod weights, 100 kernel weight, pod yield, haulm yield and oil content of groundnut. Dash *et al.* (2013) noticed that the yield attributes and yield of groundnut were significantly increased with increasing levels of sulphur up to 40 kg ha^{-1}. Pancholi (2014) concluded that increase in level of sulphur upto 60 kg ha^{-1} significantly improved the pods $plant^{-1}$, seed index, pod, haulm and kernel yield. Dutta *et al.* (2015) observed that sulphur fertilization at 30 kg ha^{-1} gave significantly higher number of pods $plant^{-1}$, shelling percentage, 100-kernals weight as well as pod yield, haulm and kernel yield. Noman *et al.* (2015) registered that application of sulphur @ 40 kg ha^{-1} significantly improved the yield attributes *viz.,* pods per plant, kernels pod and shelling percentage as well as pod yield, kernel yield and haulm yields. Naiknaware *et al.* (2015) documented that application of S @ 40 kg ha^{-1} resulted in

maximum number of pods per plant (10.44), shelling (71.16 per cent) , kernel yield (1136 kg ha^{-1}), higher pod yield (1588 kg ha^{-1}), haulm yield (2196 kg ha^{-1}), oil content (52.04 per cent) and protein content (23.14 per cent) which were significantly higher than the controlled treatment. Dutta *et al.* (2015) surmised that sulphur fertilization at 30 kg ha^{-1} gave significantly higher number of pods $plant^{-1}$, shelling percentage, 100-kernals weight as well as pod yield, haulm and kernel yield. Sabet and Amiri (2015) recorded that application of S @ 90 kg ha^{-1} significantly increased the 100 seed weight in groundnut.

Bairagi *et al.* (2017) disclosed that application of S @ 500 kg ha^{-1} through gypsum gave significantly increased plant height, number of leaves per plant, number of branches per plant, length of the pod, number of grains per pod, seed index and grain yield as well as yield in groundnut.

Effect of sulphur on seed yield of groundnut

Singh (2007) disclosed that application of 45 kg S ha^{-1} and 60 kg Ca ha^{-1} through gypsum gave significantly higher yield in groundnut. Singh and Mann (2007) observed that application of sulphur at 40 kg/ha, being at a par with 60 kg/ ha resulted significant increase in pod yield of groundnut. Giri *et al.* (2011) recorded that application of S @ 15 kg ha^{-1} through elemental sulphur significantly recorded higher kernel yield (31.11 q ha^{-1}) than control (17.97 q ha^{-1}) in groundnut.

Dutta *et al.* (2015) revealed that application of 45 kg S ha^{-1} increase in shelling percentage as well as pod and kernel yield of groundnut. Bholanath Saha *et al.* (2015) surmised that application of S @ 50 kg ha^{-1} caused an increased yield 73.4 per cent over the control in groundnut. Sisodiya *et al.* (2016) noted that application of elemental sulphur @ 20 mg kg of soil recorded the highest uptake of nutrients and significantly gave higher yield in groundnut. Kannan *et al.* (2016) disclosed that application of S through gypsum @ 400 kg ha^{-1} in split mode *viz.,* 200 kg as basal and 200 kg as top dressing recorded highest plant height, more number of filled pods per plant, 100 kernel weight, pod yield and haulm yield in groundnut.

Ruksar Banu *et al.* (2017) documented that sulphur application @ 40 kg ha^{-1} through gypsum recorded an increase in pod and haulm yield to the tune of 11.51 and 9.69 per cent respectively than elemental sulphur in groundnut. Premanandarajah and Shanika (2017) divulged that application of S @ 75 kg ha^{-1} increased the pod yield of groundnut. Pinki Pancholi *et al.* (2017) found that application of sulphur @ 60 kg ha^{-1} gave highest pod yield, kernel yield, haulm yield, biological yield and seed index over control in groundnut. Manaf *et al.* (2017) concluded that application of S @ 45 kg ha^{-1} through SSP increased the seed yied to 81.5 per cent than control in groundnut.

Effect of sulphur on oil quality of groundnut

Agasimani *et al.* (1993) observed that application of sulphur at 20 kg ha^{-1} increased the oil content in kernels of groundnut. Kadam *et al.* (2000) noted significant increment in oil and protein contents in summer groundnut with the application of sulphur at 40 kg ha^{-1}. Sahu *et al.* (2001) concluded that increasing levels of sulphur upto 40 kg ha^{-1} brought about significant enhancement in pod yield, shelling percentage, oil content, oil yield in groundnut. Patra *et al.* (2002) concluded that application of 40 kg S ha^{-1} as gypsum or pyrite significantly influenced the seed oil and protein content in groundnut.

Dayanand *et al.* (2002) revealed that protein (23.36%) and oil content (44.97%) of groundnut kernel significantly increased up to 60 kg S ha^{-1}, whereas higher oil yield (0.48 t ha^{-1}) obtained at 40 kg S ha^{-1}. Sarkar and Surendra Singh (2003) divulged that application of 30 kg S ha^{-1} through gypsum increased the oil content of groundnut. Kalaiyarasan *et al.* (2003) documented that application of S at 45 kg ha^{-1} significantly increased the oil (49.4 per cent) and protein (25.6 per cent) contents of groundnut over control. Dutta and Mondal (2006) surmised that application of 125% RDF along with gypsum @ 500 kg ha^{-1} significantly gave the highest oil content in kernel and uptake of nutrients (N, P and K) by summer groundnut. Jamal *et al.* (2006) disclosed that application of S @ 20 kg ha^{-1} through gypsum gave significant enhancement in the oil yield as well as seed protein content of groundnut. Vagharia *et al.* (2007) narrated application of sulphur @ 50 and 25 kg ha^{-1} significantly increased the oil yield as well protein yield over control. Hassan *et al.* (2007) described that S plays an important role in the chemical composition of seeds and improves the percentage of oil contents. Kalaiyarasan *et al.* (2007) reported that application of S at 60 kg ha^{-1} significantly increased the oil content and oil yield of groundnut. Tathe *et al.* (2008) divulged that application of sulphur @ 120 kg ha^{-1} through elemental sulphur recorded significantly the highest dry pod yield, oil and protein content of groundnut. Jat and Ahlawat (2009) noted that application of S at 35 kg ha^{-1} significantly increased the oil content in groundnut kernel. Kalaiselvi and Mahimairaja (2011) observed that application S increased the protein and oil content of groundnut seeds. Tejeswara Rao *et al.* (2013) surmised that sulphur at 45 kg ha^{-1} through gypsum recorded the highest oil content of the kernels. Premanantharajah and Prapagar (2013) reported that application of S @ 75 kg ha^{-1} through elemental sulphur significantly increased the protein and oil content of groundnut. Dutta *et al.* (2015) noted that oil content and oil yield of groundnut responded different sources of sulphur fertilization *viz.,* gypsum and elemental sulphur. Ruksar Banu *et al.* (2017) documented that sulphur application @ 40 kg ha^{-1} through gypsum recorded an increase in oil content of 8.18 % than elemental sulphur in groundnut.

Effect of sulphur through gypsum on groundnut

Wali *et al.* (1994) disclosed that application of sulphur @ 50 kg ha^{-1} through gypsum gave significant increase in number of pods $plant^{-1}$, shelling percentage, oil yield and haulm yield than 25 kg ha^{-1} and control. Singh and Choudhary (1996) observed that application of sulphur at

60 kg ha^{-1} through gypsum increased the plant height and number of branches $plant^{-1}$ in groundnut over 0, 20, 40 kg ha^{-1}. Sahu and Das (1997) surmised that application of sulphur @ 40 kg ha^{-1} through phosphogypsum significantly increased the pod yield and shelling percentage as compared to control and 20 kg ha^{-1} and other sources in groundnut.

Adhikari *et al.* (2000) noted that application of gypsum at 400 kg ha^{-1} significantly increased number of pods plant and shelling per cent of groundnut. Chauber *et al.* (2000) surmised that every increase in level of sulphur upto 45 kg ha^{-1} applied through gypsum brought about significant improvement in number of pods $plant^{-1}$, 100-kernels weight, shelling percentage and pod yield of groundnut over preceding levels and control. Jagadeeswaran *et al.* (2001) divulged that application of ferrogypsum in amounts equivalent to recommend dose of 400 kg ha^{-1} gypsum significantly increased the pod yield, haulm yield, shelling per cent and kernel yield of groundnut.

Kalaiyarasan *et al.* (2003) observed that application of S at 45 kg ha^{-1} through gypsum significantly increased oil and protein content in groundnut kernel. Sarkar and Surendra Singh (2003) narrated that application of 30 kg S ha^{-1} through gypsum increased the oil content of groundnut. Mandal *et al.* (2005) disclosed that application of gypsum at 400 kg ha^{-1} significantly increased the plant height, number of pods per plant, number of kernels per pod, 100 kernel weight, shelling percentage, pod and haulm yields in groundnut.

Rao and Shaktawat (2005) registered that application of gypsum @ 250 kg ha^{-1} enhanced the pod yield of groundnut than control. Jamal *et al.* (2006) documented that application of S @ 20 kg ha^{-1} through gypsum gave significant enhancement in the yield components namely seed and oil yield as well as seed protein content of groundnut.

Vagharia *et al.* (2007) concluded that application of sulphur @ 50 and 25 kg ha^{-1} through gypsum significantly increased pod and haulm yield over control. Poonia *et al.* (2008) surmised that application of 40 kg S ha^{-1} through gypsum proved significantly over 20 kg S ha^{-1} increasing the number of pods, haulm and kernel yield (38.25 and 22.95 q ha^{-1}) of groundnut

Salke *et al.* (2011) revealed that application of gypsum @ 500 kg ha^{-1} significantly influenced the yield contributing characters like number of pods plant, pod weight per plant, hundred pod weight, hundred kernel weight, shelling percentage and dry pod and haulm yield of groundnut. Gunr *et al.* (2012) reported that pod yield increased with the increasing levels of gypsum application in groundnut. Bagarama *et al.* (2012) suggested that application of the Ca and S rich gypsum improved groundnut kernel yield.

Poonia *et al.* (2013) surmised that application of sulphur at 40 kg ha^{-1} through gypsum significantly increased the nitrogen, phosphorus, potash and sulphur uptake over control in groundnut. Tejeswara Rao *et al.* (2013) reported that application of sulphur at 45 kg ha^{-1} through gypsum recorded the highest pod yield, haulm yield of the kernels in groundnut. Dutta *et al.* (2015) narrated that net returns, benefit cost ratio were found more under gypsum than elemental sulphur.

Seran (2016) described that application of gypsum @ 300 kg ha^{-1} along with NPK fertilizers gave higher seed yield in groundnut. Kannan *et al.* (2016) surmised that application of S through gypsum @ of 400 kg ha^{-1} in split mode *viz.,* 200 kg as basal and 200 kg as top dressing recorded highest plant height, more number of filled pods per plant, 100 kernel weight, pod yield and haulm yield in groundnut.

Bairagi *et al.* (2017) documented that application of S @ 500 kg ha^{-1} through gypsum gave significantly increased plant height, number of leaves per plant, number of branches per plant, length of the pod, number of grains per pod, seed index and grain yield as well as yield in groundnut. Nagesh Yadav *et al.* (2017) concluded that application of S @ 60 kg ha^{-1} through gypsum produced 13.1 and 10.2 per cent higher pod yield and biological yield than other sources and levels in groundnut. Ruksar Banu *et al.* (2017) reported that sulphur application @ 40 kg ha^{-1} through gypsum recorded an increase in pod and haulm yield to the tune of 11.51 and 9.69 per cent respectively than elemental sulphur in groundnut. Pinki Pancholi *et al.* (2017) documented that application of sulphur @ 60 kg ha^{-1} through gypsum significantly increased the pod yield and haulm yield over control in groundnut.

Effect of sulphur through single super phosphate on groundnut

Mupangwa and Tagwira (2005) recorded that P significantly increased groundnut yield on application of 8.5 kg P ha^{-1} through single super phosphate. Musa *et al.* (2015) registered that application of sulphur through SSP increase the pod yield, grain yield and oil content of groundnut. Manaf *et al.* (2017) concluded that application of S @ 45 kg ha^{-1} through SSP gave best performance for number of plants per m^2, number of pegs plant, number of pods per plant, number of seeds per pod, seed index, harvest index with an increase in grain yield of 81.5 per cent over control in groundnut. Nagesh Yadav *et al.* (2017) documented that application of S @ 60 kg ha^{-1} through SSP registered 13.9 and 21.48 per cent increase in crop growth rate than other sources in groundnut.

Effect of sulphur through elemental sulphur on groundnut

Singh (2001) observed an gradual increase in pod yield of groundnut under 20 kg S ha^{-1} through elemental sulphur. Patil *et al.* (2003) revealed that application of S @ 20 kg ha^{-1} as elemental sulphur along with recommended dose of N, P provided significantly higher kernels and haulm yield of groundnut as compared to control. Wenger *et al.* (2002) narrated that application of elemental sulphur increased the solubility of heavy metals for plant uptake subsequently resulted in higher yields of oilseed crops. Mupangwa and

Tagwira (2005) divulged that gypsum application rates of 100 kg ha^{-1} increase the growth and yield of groundnut. Tathe *et al.* (2008) concluded that application of sulphur @ 120 kg ha^{-1} through elemental sulphur recorded significantly the highest dry pod yield, oil and protein content of groundnut. Giri *et al.* (2011) disclosed that application of S @ 15 kg ha^{-1} through elemental sulphur significantly recorded higher kernel yield (31.11 q ha^{-1}) than control (17.97 q ha^{-1}) in groundnut. Premanantharajah and Prapagar (2013) suggested that application of S @ 75 kg ha^{-1} through elemental sulphur significantly increased the pod yield, protein and oil content of groundnut. Sisodiya *et al.* (2016) concluded that application of elemental sulphur @ 20 mg kg of soil recorded the highest uptake of nutrients and significantly gave higher yield in groundnut. Sisodiya *et al.* (2017) documented that application of S through elemental sulphur @ 20 mg kg of soil increased the micronutrient uptake and registered higher yield compared to other sources and levels of sulphur application in groundnut.

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