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Role of sulphur in pulse crops: A review

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Abstract

Sulphur is essential nutrient for every living cell; it is component of 21 amino acids which form protein. It is fourth key plant nutrient after nitrogen, phosphorus and potassium. Pulses are particularly sensitive to sulphur deficiency which gives low quality and less yields. sulphur plays a key role In chlorophyll and oil synthesis. Plants uptake sulphur only in sulphate form (so_4^{2-}) and it reduces to form sulphur containing amino acids and other compounds. Application of sulphur increases the nitrogen use. Efficiency of N, P, K is seriously affected under sulphur deficiency. Field experiments in many agro climatic conditions shown that application of 30 and 40 kg S/ha⁻¹ along with recommended dose given the highest yields and protein content in pulses. Moreover, this review highlights the availability of sulphur for profitable crop production, effects of different sources and levels of sulphur in pulse crops, effect of sulphur on various parameters and it also includes the sulphur absorption and translocation in plants. Moreover this review provides new sights to revisit the sulphur significance in pulse crops.

Keywords: Sulphur, protein, pulses, assimilation, deficiency, levels, sources and fertilizer

Introduction

Pulses are the main source of protein in Indian diet. Pulses are consumed as a Dal, which is a cheap source of plant protein. These are consumed because of their body building properties, presence of various amino acids. Pulses also have medicinal properties. Byproducts of pulses like pods, leaves, pod coats, bran are given to animals in the form of dry fodder. Some crops like Lobia, Gram, urdbean & Moongbean are fed to animals as green fodder. Moong plant are also used as green manure which improve soil health and it adds nutrients to the soil. A number of pulse crops are grown in India and the world. Among them major ones are Gram, Chickpea, Lentil, Field peas etc. The steady increase in the population taken together with the stagnant production of pulses over decades resulted in insufficiency in calories and imbalance in nutritional supply. The current per capita availability of pulses is about 48 grams this was decreased from previous years (statista research department, october 16, 2020).

Sulphur is essential macro nutrient required for the plant growth and development of plants. Sulphur in agricultural soils have important concern for the agriculturists all over the world because they are mostly negative, due to the decline of sulphur levels in the soil have been changed to strict environmental rules on industrial emissions. (Lewandowska M, Sirko A., 2008) [28] Sulphur is attaining importance in all the regions of the world because of frequent sulphur deficiencies in time and space several factors contributing to sulphur deficiencies were reported by many researches includes, the increased use of sulphur free high analysis fertilizers, and less use of sulphur containing pesticides along with multiple and high intensive cropping, no use of organic manures (Shivay YS, Prasad R, Pal M., 2014) [42]. leaching and erosion and sulphur containing pesticides (McNeill AM, Eriksen J, Bergström L, Smith KA, Marstorp H, Kirchmann H, Nilsson I., 2005) [30]. Restricted use of Sulphur is recognized as fourth major plant nutrient after Nitrogen, phosphorous and potassium and it plays important role in many plant process like metabolism which is dependent upon sulphur and its deficiency causes primary metabolic impairment. In plants sulphur concentrations are found to be lower than nitrogen (Saito K *et al.*, 2004) [40]. It is similar to that of phosphorus (Ali A, Arshadullah M, Hyder SI, Mahmood., IA., 2012). In all crops general pulses and oilseeds, sulphur is found in many different oxidation states in nature i: e, inorganic, organic and bioorganic forms but plants uptake sulphur mainly in the inorganic sulphate from the soil. Sulphur deficiency is found in all over the world including India. Tripathi N. *et al.*, (2003) [53]

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reported that atleast 57 million ha out of 142 million ha of arable land is deficient in sulphur and this causes heavy loss in crop yield due to its role in metabolism. Sulphur stress affects metabolic and physiological activities of plants, it also affects the carbohydrate (sugar and starch) metabolism. In sulphur deficient crops sugars were decreased and starch was accumulated in leaves. Sulphur is a constituent of essential compounds i: e, cysteine, methionine, several coenzymes (Biotin, coenzyme A, Thiamine Pyrophosphate and lipolic acid), thioredoxins, and sulpholipids. Cysteine is required for the synthesis of protein and glutathione (GSH) synthesis or functions as a sulphur donor for methionine and secondary metabolite biosynthesis. Glutathione helps to control the concentration of reactive oxygen species (ROS) and participates in the regulation of sulfate uptake and in the detoxification of heavy metals.

Sulphur chemistry in soil

Sulphur present in rocks is in the form of sulfide (Metamorphic and igneous), in soil it occurs in combination with organic matter, it is also present in oceans, industrial wastes, and as gaseous form in the atmosphere. Hence sulphur is present in soil in both organic and inorganic forms. Amount

of inorganic and organic sulphur depends upon soil pH, texture, organic matter calcium carbonate and other soil characteristics (Dhamak AL, Meshram NA, Waikar SL., 2014) [12]. Out of many inorganic forms of sulphur, sulphide, elemental sulphur, sulphate etc. sulphate form of sulphur is available to the plants for their growth and development. Indian soils contains about 30% of total sulphur in organic combination in alluvial soils where as in Mollisols of tarai region it reaches to 70% (Singh SK, Dey P, Latore AM, Singh S, Sharma PK, Singh CM, Singh YV, Kumar., 2015) [46]. Sulphur is deficient in highly weathered soils like (Oxisols and Ultisols) (Sabir M, Hanafi MM, Hakeem KR., 2015) [39]. Sulphur precipitation is found in the form of sodium sulphate or calcium, magnesium. In marshy lands we can see the accumulation of pyrites in large amounts in the form of sulphide metals (Havlin JL, Beaton JD, Tisdale SL, Nelson WL., 2005) [21]. Sulphur balance in soil and plant system is based on plant uptake, volatilization, and mineralization. sulphur requirement varies with the crops. It is generally in the order of Cruciferae > Leguminosae > Poaceae. (Table-1) (Lucheta AR, Lambais MR., 2012) [29]. For producing one ton seed of pulses we require 8 kg of sulphur (Jamal A, Moon YS, Abdin MZ., 2010) [26].

Table 1: Pulse crop demand for sulphur in different agro-climatic conditions.

S. No	Crop	Sulphur Requirement	Agro-climatic conditions and location	Soil	Reference
1.	Black gram	40 kg ha ⁻¹	Humid subtropical (Kumarganj, Faizabad)	Sandy loam	Niraj VPS, Prakash V., 2014 [34].
2.	Soya bean	40 kg ha ⁻¹	Humid subtropical (Ambikapur)	Sandy loam	Paliwal AK, Vajpai SK, Vajpai K.,
3.	Mung bean	45 kg ha ⁻¹	Humid subtropical (Varanasi)	Sandy clay loam (Inceptisol)	Tripathi PK, Singh MK, Singh JP, Singh, 2012 [54].
4.	Soya bean	40 kg ha ⁻¹	Tropical wet and dry (Dharwad)	Vertisol	Hosmath JA, Basavaraj GT, Agasimani, SC, Jahagirdar S, Babalad HB, Athoni BK, 2014 [23].
5.	Pigeon pea	20 kg ha ⁻¹	Subtropical (Nagpur)	Dark clay	Deshbhratar PB, Singh PK, Jambhulkar AP, Ramteke DS., 2010 [9].
6.	Soya bean	20 kg ha ⁻¹	Tropical wet and dry (Hyderabad)	Sandy loam	Anil D, Sagar GCV, Sreenivas G, Sharma SHK., 2017 [3].
7.	Sun hemp	40 kg ha ⁻¹	Subtropical (Pratapgarh, UP)	Sandy loam (Inceptisol)	Saha S, Saha M, Saha AR, Mitra S, Sarkar SK, Ghorai AK, Tripathi MK., 2013 [41].

Absorption and translocation of sulphur

Sulphur is an essential plant nutrient taken up by the plants as SO_4^{2-} form from the soil, it is reduced and incorporated into the plant cells as bioorganic compounds. Hermsen C, *et al* (2010) [22] reported that conduit of so_4^{2-} assimilation is regulated in demand determined manner in seed plants. Autotrophic plants have a set of transporters and enzymes that referee to uptake and absorption of so_4^{2-} and exchange into organic sulphur compounds. Hell and Hillebrand, (2001) [20] revealed that availability of sulphur promotes growth and development of higher plants. SULTRI 3, a high affinity transporter is localized to the phloem and mediate long expanse translocation from roots (source organs) followed by leaves and shoots (sinks) (Yoshimoto *et al.*, 2003) [57]. Yield and quality of legume seeds are decrease by the quantity of sulphur partition to the seeds. The amino acid S-methyl methionine (SMM), a methionine lacking in originality and a long-distance transport form of condensed Sulphur and whether SMM phloem load and source-sink translocation are significant for the growth and metabolism of pea (*Pisum sativum*) plants.

Sulphur deficiency in different regions

In India 135,000 soil samples revealed that 42.3% samples are

deficient in available sulphur and 300 districts are suffering from sulphur deficiency as compared to 70 districts (Tandon HLS *et al.*, 2010) [50]. Soils of semi –arid tropical regions severe conditions may be noticed and eastern gangetic plains of the country (Singh SK, Sharma PK, Dey P, Singh YV, Latore AM, Singh CM, Singh S, Kumar D, Kumar O, Yadav SN, Verma SS., 2015) [46]. Singh and Sonu Kumar (2012) [44] revealed that in pulse growing upland red soils deficiency is comparatively high (92.0%) than Black soils (37.0%) and alluvial soils (48.0%). In India crop removal of sulphur is to be estimated as 1.26 Mt, but recovery through fertilizers is only about 0.76 Mt. (Tiwari KN, Gupta BR., 2006) [52]

Effect of sulphur on various parameters

Sulphur limitation in pulse crops showed reduced growth and photosynthetic rates (Giordano *et al.*, 2000) [18]. Adverse effect on sulphur deficiency on biochemical process and inorganic nutrition may led to the reduce in the growth and lastly may effect in decline in the yield of the chickpea (Badruddin and Karmoker, 2001) [6]. Sulphur limitation showed strong reduction in photosynthesis and it correlate with a substantial decline of chlorophyll a/b binding protein and rubisco (Jamal, 2006) [25]. Sulphur deficient plants give lower yield and have a reduced nutritional value. Sulphur

deficiency severely affects activity of photosynthesis. The chlorophyll content was condensed because of universal decline of PSII and PSI and the related light harvesting antenna. In sulphur deprived plants Rubisco content was significantly decreased. The imbalance between carbon fixation and photosynthesis, and between PSII and PSI led to broad decrease of the photosynthetic electron carriers chromatographic investigation results show that level of starch substance was advanced and level of monosaccharide's was lower in the sulphur deprived plants. while there are no changes in the metabolite levels were observed in the calvin cycle or TCA (Lunde *et al.*, 2009). Sulphur is an essential macro nutrient that accelerates the plant growth (Thomas *et al.*, 2000). Sulphur content resulted optimistic effect on seed yield and its value is important and visible, when sulphur substance is near to the ground in soil (Ahmad *et al.*, 2007; Malhi *et al.*, 2007). Due to the deficiency of sulphur, biological nitrogen fixation, nodulation and yield of peanut crops are decreased. Varin *et al.*, (2010) ^[55] showed whether the outcome of sulphate adding on nitrogen fixation resulted from a stimulus of host plant growth, a definite affect of sulphur on nodule metabolism or nodulation due to the application of sulphate form of sulphur there is an increase in whole plant dry mass, nodule biomass and root length, expressed on a root length basis. Nitrogen fixation was significantly reduced in sulphur scarce plants because of a low nodule expansion but also due to low nitrogenase and leghaemoglobin production.

Importance of sulphur in pulse cropping

Sulphur is a divisive chemical factor (Ostowska *et al.*, 2008). The concentration of sulphur was found to be highest in oil seed (1.1-1.7%), followed by pulses (0.24-0.32%) and the least (0.12- 0.20%) in cereals (Singh, 2001). It is linked with nitrogen metabolisam and its application increases the nitrogen uptake by the plants (Mondal MMA, Badruddin M, Malek MA, Hossain Mb, Puteh AB., 2012) ^[33]. Visual sulphur deficiency symptoms include chlorosis on young leaves and reduced plant growth (stunted growth, thin and woody stem, reduced leaf size, premature defoliation etc.) and its toxicity symptoms include intervenal necrosis, chlorosis, mottling in young leaves, bluish green appearance of older leaves, bushy appearance of lateral branches (Chandra N, Pandey N., 2016) ^[10]. It causes the acidification of atmosphere on one hand, on other hand it is a required constituent of amino acids e.g. cysteine and methionine, which is a mandatory for protein production essential for growth and biomass. It is classify as a secondary nutrient which is obligatory for all plants for the development and metabolism (Vidyalakshmi *et al.*, 2009) ^[56]. Sulphur has a amount of oxidising function in plant nutrition and is a constituent of Fe-S proteins called Ferridoxin, which is responsible for transfer of electrons in the photosynthesis (light dependent) reactions during its first phase (Randall, (1988); Goswami, (1988) ^[19]; Petrovic and Kastori, (1994); Marschner, (1995)). Sulphur has a thoughtful effect on create absorption area gripping PAR and as an outcome on yield of the crops. with the function of S up to 20 kg/ha has significantly increased the total number of nodules and active nodules (Ganeshamurthy and Readly, 2000) ^[16]. Varin *et al.* (2010) ^[55] experimental the result of sulphate addition on nitrogen fixation resulted from a encouragement of host plant growth, a definite effect of Sulphur on nodule metabolism or a definite effect of Sulphur on nodulation. In black gram, relevance of gypsum at the rate of 60Kg/ha considerably results advanced pod length, seed/pod to 1000 seed weight

and function of 20 kg S/ha also extensively increased the dry matters yield of soya bean (Ganeshamurthy and Reddy, 2000) ^[16].

Interaction of sulphur and nitrogen in soil and plant

Intensive agricultural practices with the use of high analysis fertilizers and improved cultivars offers the exhaustion which results in nutrient difference in soil. Fazili *et al.*, (2008) experimental that require of sulphur limits the effectiveness of added N, so it is essential to add sulphur in soil to attain maximum competence of applied nitrogenous fertilizer. Sulphur and nitrogen play a central role in the combination of proteins, these nutrients are highly inter-related. sulphur and nitrogen relatives were report in many studies. (Jamal *et al.*, 2005; 2006a; 2010) ^[24, 25, 26].

Effects of sources of sulphur in pulses

Anil Kumar Patel, Triyuginath, Anurag prajapati, Vivek Kumar Singh. (2018) ^[4] reported that field experiment to evaluate the effect of different level and sources of sulphur on growth and yield of Black gram. Sulpur sources viz; gypsum, elemental sulphur and ammonium sulphate were used at different levels 0, 20, 40 and 60 kg/ha. Application of Zypsum 40kg S/ha recorded highest growth (plant height, leaf area index, dry matter production and number of branches per plant), yield components (no of pods/plant and no of seeds/pod) and yield (grain and hulum) in black gram. R. RS. Sodiya *et al.* (2016) ^[38] conducted a pot experiment to examine the effects of different sources of sulphur (cosawet, gypsum, bentonite and elemental sulphur) on kharif ground nut with sulphur sources viz; 0, 5, 10, 15, 20 mg sulphur/kg. In this experiment application of bentonite sulphur 20 mg/kg produced significantly. The highest K content (0.568%) at 60 DAS as compared to remaining doses of sulphur. Moni sankar Bera and Gautam Kumar Gosh (2012) conducted experiment on sulphur source in green gram viz; Zypsum, Magnesium sulphate and single super phosphate and levels of sulphur 0, 20, 40, 60 and 80 kg S/ha, maximum seed yield was obtained with Single super phosphate and magnesium sulphate @ 60kg S followed by gypsum. N. C. Banik and K. Sen Gupta (2012) conducted an experiment with different sulphur sources and levels they have obtained highest seed yield by applying 30 kg SSP along with recommended dose. S. P. singh, Yogesh Kumar and Sonu Singh (2012) ^[44] conducted experiment on different sources and levels of sulphur in green gram, results reveled that plant height, branches per plant, nodules per plant and test weight was found maximum with 40 kg S/ha as gypsum. Tiwari *et al.* (2003) report that function of sulphur @ 40kg ha⁻¹ gave significantly highest yield of wheat, mustard, rice and chickpea more than rejection sulphur application treatment followed by same level of gypsum in farmers fields. Bandopadhyay and Samui (2000) ^[7] noticed that gypsum and single superphosphate sources performed better and recorded significantly higher yield and yield attributing characters of groundnut over pyrites. Tomar *et al.* (2000) noticed that soybean seed yield was increased by application of 25 kg S ha⁻¹, with no further significant increase as the rate was increased up to 75 kg S ha⁻¹. Gokhale *et al.* (2005) declared that use of sulphur at 40 kg ha⁻¹ either through gypsum or single super phosphate recorded the higher seed yield, oil, and protein contents of soybean. Wadile *et al.* (2005) observed that significantly higher sesame seed yield (645 kg ha⁻¹) was obtained when 15 kg ha⁻¹ of sulphur applied through single super phosphate was applied over the control.

Effect of levels of sulphur in pulses

Sita ram kumawat, S. L Yadav, Manoj and M. K. Khistriya (2014) ^[45] has obtain maximum plant height, leaf area index, number of branches per plant, dry matter content were observed in 30 kg S/ha. With respect to yield attributes and yield the results indicate highest weight of 100 seeds, number of pods, straw yield was found maximum with application of 30 kg S/ha in green gram. M. Arun Raj, D. vasanthi and M. David Israel, Mani singh (2015) obtained highest growth parameters like plant height, no of leaves per plant, number of branches per plant, total dry matter production and give up attribute like no of seeds per plant, no of pod per plant, thousand seed weight, grain yield were recorded with the application of 30 kg sulphur along with recommended dose of fertilizer in Green gram. H. R Patel and H. F Patel (2013) ^[37] conducted experiment on three levels of sulphur form in gypsum (0, 20, 40 kg/ha), 40 kg S/ha recorded significantly maximum no of branches per plant, plant spread, no of nodules per plant, dry matter per plant, seed yield, protein content as well as highest net realization. Anil kumar patel, Triyuginath, Anurag Prajapati, vivek kumar singh and Saurabh Kumar Pandey (2015) conducted this experiment to evaluate the effect of different level and source of sulphur on growth and yield of black gram. Sulphur sources viz; gypsum, elemental sulphur and ammonium sulphate were used at different levels viz; 0, 20, 40 and 60 kg S/ha among sources gypsum registered its significant superiority over other sources, with respect of levels of application of 40 kg S/ha recorded highest growth (plant height, leaf area index, dry matter production, number of branches per plant and also yield components like no of pod per plant and yield. Ravi *et al.* (2008) conducted a field experiment on Vertisols of Main Agricultural Research Station, Dharwad during rabi season during 2002-03 indicated that application of 30 kg S ha⁻¹ improved the growth parameters like plant height (114.7 cm), number of leaves (94.5), number of primary branches (14.3), secondary branches (21.2) and dry matter production (3181.4 kg ha⁻¹) of safflower at harvest over rest of the treatments. Patel *et al.* (2008) revealed that application of 40 kg S ha⁻¹ recorded significantly higher plant height (47 cm), plant spread (41 cm) and branches plant⁻¹ (6) in groundnut over control. Lallu *et al.* (2008) found that maximum value of LAD (52.2) and LAI (0.93) of Indian mustard were recorded in plants received 60 kg S ha⁻¹ while value of CGR (7.6 g m⁻² day⁻¹) and number of branches (20.3) were noticed maximum in plants fertilized with 40 kg S ha⁻¹ along with RDF. Sarkar *et al* (2006) Application of different levels of gypsum significantly increased the leaf area index, flower to pod ratio and thereby yield of groundnut and increased further when zinc applied as zinc sulphate along with gypsum. The highest kernel yield was obtained with gypsum application at 750 kg ha⁻¹ + Zn at 25 kg ha⁻¹, followed by gypsum at 500 kg ha⁻¹ + Zn at 25 kg ha⁻¹. Among the two cultivars, cv. G201 (semi-spreading type) was responsive to gypsum and zinc application and superiority to cv. TMV2 (bunch type) in groundnut crop.

Conclusion

Sulphur is one of the most important nutrients for growth and development of plant, most of it is present as sulphur containing amino acids (Cysteine, Methionine), glutathione, proteins and sulpholipids in pulses and oilseeds. Use of high analysis fertilizers containing less amount or no sulphur combined with intensive cropping system led to the sulphur deficiencies in plants. Sulphur fertilizers in India are

Bentonite, gypsum, elemental sulphur, pyrites. Sulphur is also present in combinations of nitrogen (ammonium sulphate, ammonium phosphate sulphate), phosphorous (single super phosphate, double super phosphate, triple super phosphate), potassium (potassium sulphate, potassium magnesium sulphate) and micro nutrient fertilizers (copper sulphate, manganese sulphate, zinc sulphate). Optimizing the sulphur availability in appropriate quantities and its synchrony with plant demand increases the yields levels in pulses. Nitrogen, phosphorous, potassium efficiency will be seriously affected under sulphur deficiency. In sulphur deficient soils higher yields, quality and profits are possible only when sulphur application is made as a part of fertilizer application.

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