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SMART SULPHUR MANAGEMENT FOR INCREASED PRODUCTIVITY AND QUALITY OF INDIAN MUSTARD (*Brassica juncea* L.)

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Sulphur as it is rightly called the fourth major secondary plant nutrient for all significant crops for its essentiality toward growth, development and yield. It plays a pivotal role in different physiological and biochemical functions in the plant. However, sulphur deficiency is one of the significant nutritional deficiency in the plant as more than 70 countries around the world are facing it, and India is no exception. Sulphur is essential in a plant for promoting oil synthesis, along with a constituent of seed protein, amino acid, enzymes, chlorophyll and glucosinolate. Sulphur is even more critical when it comes to repassed and mustard where it plays a vital role in determining yield, oil quality and quantity, and resistance to various stress. Among all the field crops; rapeseed and mustard have the highest requirement of sulphur. Various researches concluded that sulphur increased the yield of mustard by 12 to 48% under the irrigated condition and 17 to 124% under rainfed conditions. If we consider the Agronomic efficiency, each kilogram of sulphur increases the yield of Indian mustard by 7.7 kg. If we consider the uptake of sulphur by Rapeseed (*Brassica competes* and *Brassica rapa L.*) with a cereal like Barley, it has been observed that the former requires 3-10 times more sulphur.

However, the availability of sulphur to the plant for uptake is decreasing day by day. The prime reasons can be argued that of using high yielding crop varieties and multiple cropping per year coupled with high analysis sulphur-free fertilizers that are too in the absence of regular supply of organic manure in the soil. Currently Indian is facing a massive gap of N: P_2O_5: K_2O: S which is around 14.7: 5.1: 1.6: 1 a level far below the desired limit and hence required urgent attention to enhance it through the adoption of advanced techniques developed for sustainable sulphur management. As per the new Oilseed mission

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of India; the average productivity of rapeseed and mustard is only 1145 kg/ha which needs to be enhanced to 2562 kg/ha by the end of 2030 for self-reliance in edible oil. Attaining such level of productivity is not possible without comprehensive sulphur management practice. A deficiency oriented nutrient management is the only way forward to achieve the goal.

Sulphur in soil

Sulphur in the soil generally remains as a compound form of a heterogeneous mixture of plant residues, animal and soil microorganisms. The mobility of sulphur in soil is like nitrogen as it moves very rapidly, especially in sandy soil. Like nitrate, sulphur is also negatively charged and subjected to leaching into the subsoil. As a result, the availability of sulphate is less in topsoil (upper 30 cm). IN the subsoil the sulphate is absorbed by the iron and aluminium oxides. The accumulation of sulphate in subsoil depend upon the acidity of the subsoil; with increasing acidity, the accumulation of sulphates in the subsoil also increases. This accumulation relies on the mineralization of organic matter to sulphate and mineralization depends upon the C: S ratio. The critical range of C: S ratio lies in between 200-300:1. When the C: S ratio reaches below 200: 1, the net mineralization happens, and if it is above 300: 1, the immobilization occurs. The immobilization occurs when the organic residue contains less amount of sulphate as the microbes in soil tends to lock it down. The sulphate loss can also occur due to volatilization as hydrogen sulphide (H_2S) under waterlogged condition.

Most of the Indian soils especially the soils of Indo- Gangetic plains, red, lateritic and hill soils are deficient in sulphur while coastal soils have an abundant level of sulphur. The sulphur deficiency has also been reported form calcareous soils because of their low organic matter content. On the other hand, most of the saline soils and acid sulphate soils of mangroves contain an excessive amount of sulphur which is toxic to plants. So, it can be concluded that the availability of sulphate in the soil varies quite a bit from place to place.

The response of Indian mustard to sulphur

Indian mustard is specifically sensitive to sulphur availability. It requires around 0.33-0.40% sulphur in leaves for obtaining 90% of its potential yield. In the case of plant tissue, it requires one part of sulphur for every 15-20 parts of nitrogen for optimum growth and yield. On a dry matter basis, the sulphur should occupy 0.1-0.6% as an optimum range. The

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partitioning studies reveals that the maximum S concentration lies in the leaves followed by stem while the lowest in roots. During the sulphur deficiency, accumulation of amides and carbohydrate happens in leaves which in return hampers the development of chlorophyll and causes stunted plant growth and yellowing of young leaves. Sulphur is also behind the glycoside of mustard which causes distinct odour and pungency.

It has been observed that yield attributes of Indian mustard increased significantly with an increasing application rate of sulphur upto 45 kg/ha; however, the optimum seed yield and oil yield of Indian mustard occurred at about 20 kg/ ha of sulphur. Again, the application of sulphur in the even higher rate (100 kg/ha) causes higher uptake of sulphur in the plant. Deficiency of S results in severe yield losses to Indian mustard, due to its higher demand for the synthesis of protein, co-enzymes, S- containing amino acids and glucosinolates. When the sulphur level falls below the desired level, it causes disruption of nitrogen metabolism.

Optimum sulphur management in Indian mustard-based cropping system

Application of sulphur at a rate of 40 kg/ ha has been found superior in the majority of Indian mustard-based cropping system. Not only the application rate but the source is also significant for optimum sulphur management. Bentonite S as a source of sulphur gives significantly higher growth, yield attributes and yield as compared to gypsum and wettable sulphur. Genotype and its response is also an essential factor as varieties like Varuna and Kranti produced higher yield with and sulphur application rate of 20 kg/ha as compared to Pusa bold with 30 kg/ha of sulphur. When Indian Mustad is grown under Indian mustard-black gram cropping sequence, the application of sulphur at a rate of 20 kg/ha is sufficient to meet the demand for both crops. Another interesting fact is that although protein and oil content is negatively correlated; but the application of sulphur in proper amount resulted in increments in both factors. The increase in oil content of seed mustard is related to increase in in acetyl-CoA carboxylase activity, which is also the precursor for oil synthesis. Foremost, sulphur is a constituent of methionine, the first amino acid required in the protein synthesis (acetyl-CoA carboxylase). Subsequently, sulphur is associated with the proper functioning of nitrate reductase, the enzyme regulating the flow of NO_3-N into the amino acids and finally into protein synthesis. Although the application of sulphur resulted in an increase of oil

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contents in all rapeseed and mustard species, the best result has been observed in Indian mustard.

Another famous cropping sequence, especially for the desert area, is guar- *taramira* sequence. In this sequence application of 40 kg, sulphur/ ha has been found to be best in maximum cases.

Method and time of sulphur application

Application of right amount of sulphur is not the only aspect of holistic sulphur management for improved sulphur use efficiency; it also includes the proper method and time of application. The foremost step should be the initial soil analysis to get a fair idea about the status of all available nutrients in the soil. Nutrient management with any nutrient is not straight forward because of interactions among nutrients and sulphur is no exception. The second most crucial point that should be considered is the physiological stage of the plant to determine the proper timing. Just like the nitrates, sulphur is leachable hence smaller split doses during the various nutritionally critical phase is essential. This factor becomes even more necessary in case of sandy soils. The most commonly followed method is band application; however, labour can be saved in case of broadcasting which is possible if sufficient rainfall has occurred or assured irrigation is present. Various researches indicated that a similar quantity of seed yield could be obtained in case of broadcasting as compared to side dressing if continuous moisture is maintained in the field. It is because of the fact that the mineralization rate of sulphur is highest for *Crucifers* (57- 85% of total applied sulphur) while the lowest is for legumes (47% of total applied sulphur). The best time of sulphur application is before the sowing has been done. Although; if the sulphur is not used before the planting, application during the bolting stage can significantly restore the yield while during flowering; it can partially fill up the deficiency gap. Inside the plant; sulphur is less mobile than nitrogen. The requirement of sulphur in mustard is more during the initial stage; hence complete doses should be applied before the bud initiation. The fertilizer application should be made if the nitrogen: sulphur ratio reaches above 15: 1.

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Source of sulphur and integrated use strategy

Sulphur does not have any cheaper nutrient source; hence judicious use is the key to economic sulphur management. Based on different requirements, the right source should be selected, as mentioned below:

Table 1:various sources and management approach of sulphur-containing fertilizers

S No.	Fertilizer	S content (%)	Management approach
1.	Elemental S	85	Best suitable for fine-textured calcareous soil. Should be applied 3-4 weeks before planting.
2.	Ammonium sulphate	24	Suitable for integrated use along with nitrogen. Best suitable for topdressing.
3	Pyrite	22	Best suitable for surface dressing in alkaline soil
4	Gypsum	18	Most suitable for the crop with high calcium demand
5	Potassium sulphate	18	Best suitable for integrated application with potassium in chlorine sensitive crops.
6	Single superphosphate	16	Integrated use with phosphorus as basal dose.
7	Zinc sulphate	15	Used in plants which also requires zinc in a higher amount.

[Source: Rathore *et al.*,2015]

If pyrite is to be used in calcareous soil; it should be in fine powder formed and should be applied 7-10 days before the sowing. Sulphur can also be used as fortified fertilizer such as mono ammonium and diammonium phosphate with 5% and 20% sulphur respectively. When sulphur is applied as granulated triple superphosphate and diammonium phosphate, the oxidation rate is much higher in both acid and calcareous soil.

Sulphur is also a great source of coating material for urea as control released fertilizer. Generally, the sulphur content in sulphur coated urea is 14-20%. This kind of mechanism is particularly helpful in case of delayed requirements of nitrogen.

Another aspect of sulphur management in Indian mustard is that use of organic matters. Application of 5-ton FYM along with 20 kg/ha of sulphur is mostly recommended. In the absence of FYM, pressed can also be used.

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Conclusion

Sulphur, currently being considered as the fourth most crucial plant nutrient, is essential for higher production of crops, especially rapeseed and mustard. Sulphur is also responsible for three essential amino acids, namely cysteine, cysteine and methionine and hence crucial for protein synthesis. Current estimation suggests that till 2025, 2 million tonnes/year of sulphur will be removed from the soil. As compared to other significant nutrients, sulphur is much cheaper yet provides more return per unit money invested. Sustainable, balanced and integrated sulphur management not only increases the yield of Indian mustard but also the quality of it. With proper management, sulphur can play an important role to fill the vegetable oil production gap India is currently facing.

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