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Role of Sulphur in Plant Activity

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The semi-arid tropics (SAT), spread over 11.6 million km^2 worldwide, is home to millions of poor people. The soils are low in fertility and degraded to varying extent. The climate is characterized by undependable rainfall, high average temperatures and water stress situations for crop growth. ICRISAT's on-farm community watershed research in Asia revealed that the SAT's subsistence agricultural systems have soils depleted not only in macronutrients but also in micronutrients such as zinc and boron and secondary nutrients like sulphur beyond the critical limits. Widespread (80-100%) deficiencies of micro and secondary nutrients were observed in farmers' fields in India. Substantial increase in yields by 20 to 80% due to micronutrient amendments, and a further increase by 70 to 120% due to micronutrients and adequate nitrogen (N) and phosphorus (P) amendments in a number of crops (maize, sorghum, mung bean, pigeon pea, castor and chickpea in farmers' fields were observed (Rego *et al*., 2005).

Sulphur is essential for plant growth and functioning. Sulphate taken up by the roots is the primary sulphur source for growth, but additionally plants are able to utilize absorbed sulphur gases by the shoot. Prior to its assimilation sulphur needs to be reduced and cysteine is the primary precursor or sulphur donor for other plant sulphur metabolites. Sulphur is of great significance for the structure of proteins and functioning of enzymes and it plays an important role in the defense of plants against stresses and pests. Sulphur metabolites such as glutathione provide protection of plants against oxidative stress, heavy metals and xenobiotics. Secondary sulphur compounds (viz. glucosinolates, γ-glutamyl peptides and alliins), phytoalexins, sulphur-rich proteins (thionins), localized deposition of elemental sulphur and the release of volatile sulphur compounds may provide resistance against pathogens and herbivory. Plant species vary largely in sulphur requirement and an adequate and balanced sulphur nutrition is crucial for their production, quality and health. In agricultural ecosystems, the occurrence of sulphur deficiency of soils can easily be corrected by the application of sulphur fertilizers, which additionally prevents negative environmental side effects such as leakage of nitrate to drainage water. Plants in natural ecosystems generally have an adequate sulphur supply, which partly originates from atmospheric sulphur inputs. Humans and animals rely on plants for their reduced sulphur, and plant sulphur nutrition has a decisive effect on food quality, e.g., availability of methionine, bread making and malting quality, and on health, because some secondary sulphur compounds have significance as phyto pharmaceuticals (Zhao *et al*., 2008).

Sulphur is an essential nutrient for plants and is considered as the fourth major plant nutrient after nitrogen, phosphorous and potassium. Total sulphur content in plants tissue ranges from 0.3% to 7.6%; the latter is found in plants from gypsum soils (Tabatabai, 1986;

Ernst, 1990). In general, plants rely on sulphate taken up by roots as the sulphur source for growth. In agro-ecosystems sulphur supply is not always optimal for plant growth and quality (Schnug, 1990). The abundance of sulphate in the pedosphere varies widely and may originate from weathering of rock, mineralization of organic sulphur, ground or runoff water, atmospheric deposition of sulphur gases and fertilizers. The majority of the sulphate taken up by the plant is reduced and metabolized into cytosine and methionine, both of which are highly important in proteins (Hawkesford and De Kok, 2006; Haneklaus *et al.*, 2007). Accordingly, the assimilation of sulphur and nitrogen are strongly interrelated and the organic molar N/S ratio may reflect the sulphur status of the plant, which usually ranges from 30 to 35 for sulphur sufficient crop plants (Durenkamp and De Kok, 2003). Plants contain a large variety of other organic sulphur compounds, which play an important role in plant functioning and adaptation to the environment. The role of sulphur for plant production in agro and natural ecosystems will be evaluated. It is evident that the sulphur supply to the plant has a decisive effect on the growth, the performance and fitness, and the resistance of plants to biotic and abiotic stresses. Furthermore, sulphur strongly affects food quality of crop plants.

Variety of sulphur compounds and importance of sufficient sulphur nutrition:

Sulphur occurs in the environment in a variety of oxidative states that range from –2 in its most reduced form (sulphide - S^{-2}) to +6 in its most oxidized form (sulphate - SO_4^{2+}). In the aerobic atmosphere of the Earth inorganic sulphur occurs pre-dominantly in the form of sulphate. The main reserve of sulphur are oceans (Giordano *et al.*, 2005), where sulphur exists primarily in the form of inorganic sulphate, while in the earth sulphur can be found mostly as sulphate minerals, such as gypsum, or sulfide minerals, such as pyrite. Sulphur dioxide (SO_2), mainly, and hydrogen sulphide (H_2S) are emitted to the atmosphere as a result of volcanic activity, decomposition of biological tissues and anthropogenic activities. All sulphur compounds are in constant flux (termed global sulphur cycle) between oxidized and reduced states through the action of living organisms and chemical processes. Sulphur is necessary for proper growth and development of living organisms, however, it is attributed rather catalytic and regulatory than structural functions because it is much less abundant than other microelements. For example, there is on average about 30-fold more nitrogen, 8-fold more potassium and 2-fold more phosphorus than sulphur in plant shoot dry matter (Marshner, 2005). The plant biomass consumed as food and feed serves as the main source of organic sulphur for animals and humans (Komarnisky *et.al.*, 2003). Plants, bacteria and fungi, contrary to animals, are able to assimilate inorganic sulphur and incorporate it into organic compounds. Inorganic sulphur must follow a cascade of reactions to be changed into organic sulphur compounds. Plants utilize sulphate for the synthesis of diverse primary and secondary metabolites The first organic compound synthesized in the sulphate assimilatory pathway is cysteine (Cys). It is an important amino acid incorporated into various proteins, and a precursor of numerous essential compounds such as methionine, *S*adenosyl methionine (SAM), *S*-methylmethionine, [Fe/S] clusters, hormones, vitamins and enzyme cofactors. Disulfide bonds formed in proteins between the thiol groups of Cys residues play crucial roles in forming and maintaining the tertiary structures of proteins. Some Cys-containing metabolites, including glutathione (GSH), phytochelatins and thionins function in response against environmental stresses. Organic compounds containing sulphur are also responsible for the specific taste and smell of onion, garlic and other valuable vegetables and herbs used in the kitchen or in traditional medicine.

Uptake, assimilation and distribution of sulphur:

The uptake and reduction of sulphate in plants and its subsequent assimilation into organic sulphur compounds is highly coordinated (Hawkesford and De Kok, 2006). The uptake and distribution of sulphate in the plant is mediated by sulphate transporter proteins, which are encoded by a sulphate transporter gene family consisting of at least 14 members. The sulphate transporters have been classified in five different groups according to their cellular and subcellular expression and possible functioning. There is a distinct group of sulphate transporters which mediate the uptake of sulphate by the roots that have a high affinity for sulphate (Km 1.5–10 μM). Another group of sulphate transporters are involved in the vascular loading and unloading of sulphate, however, these transporters have a lower affinity for sulphate. There are also distinct transporters involved in the vacuolar exchange of sulphate, whereas the functions of other transporter groups are less well characterized. The uptake and distribution of sulphate and the level of expression of the sulphate transporter genes are directly controlled by plant sulphur status (Buchner *et al.*, 2004; Hawkesford and De Kok, 2006). It needs to be further evaluated whether the local in situ sulphate concentration or that of a metabolic product of sulphate assimilation, such as cysteine or glutathione, is involved as signaling of the regulatory control of the different sulphate transporters.

Crop sulphur removal:

Crop harvest removes S from the field. Corn grain contains about 0.5 pound of S for every 10 bushels of grain, so about 10 pounds of S per acre is removed by corn that yields 200 bushel per acre. Soybean grain removes about 1.7 pounds of S per 10 bushels of grain – about 10 pounds of S per acre at 60 bushels per acre. Alfalfa hay removes about 5-7 pounds of S per ton of hay, so upwards of 20-30 pounds of S per acre per year. Ten years ago crop S removal was generally less than atmospheric S deposition, but now crop removal is equal to or greater than S deposition in most situations. While deposition has decreased in the last 15 years, crop yield and S removal continue to increase. Over the past years, corn and soybean grain yields have increased about 1.8 and 0.4 bushels per acre per year, respectively. Increasing grain yield increases results in greater crop S removal from the field.

Diagnosing sulphur deficiency:

In recent years, sulphur (S) deficiency has been diagnosed in corn, soybean, alfalfa, and wheat in the Midwest including India. There a number of reasons why S deficiency appears is becoming a more common occurrence, including reduced atmospheric S deposition, continued and increasing crop removal of S, greater use of no tillage, and high amounts of crop residues. It is wise to consider S deficiency when troubleshooting crop growth problems where yellowing of the crop is the primary symptom.

Sulphur deficient crops typically have an overall yellow appearance similar to N deficiency. However S is not as mobile in the plant as N, so lower leaves do not show more severe deficiency symptoms than the upper leaves. If S deficiency is misdiagnosed as a N deficiency the application of fertilizer N will make the S deficiency worse, so tissue sampling is recommended to positively identify which nutrient is deficient. In corn, S deficiency may also cause leaf striping which is easily confused with magnesium, manganese, and zinc deficiency. Areas of sulphur deficiency (pale green) and sufficiency (dark green) in an India corn field caused by variations in soil properties. Young corn that is sulphur deficient may show striping as well as an overall yellow color (Camberato 2017).

Conclusion:

Sulphur is an essential nutrients for plant growth and development. Sulphur and its secondary metabolites has importance in proteins and functioning of enzymes, defense of plants against stresses and pests and provide protection against oxidative stress, heavy metals and xenobiotics. Sulphur is essential element in various amino acids require for plant. Sulphur transporter proteins has importance in uptake and distribution of sulphur to different plant parts. Furthermore, plant show many deficiency symptoms in sulphur deficiency, identify and correction of sulphur deficiency is must for proper plant growth.

References:

1. Buchner, P., Takahashi, H. and Hawkesford, M.J. (2004). Plant sulphate transporters: co-ordination of uptake, intracellular and long-distance transport. *Journal of experimental botany*, *55*(404): 1765-1773.
2. Camberato, J. & Casteel, S. (2017). Sulphur deficiency. *Purdue Univ. Dep. of Agronomy, Soil Fertility Update*.
3. De Kok, L.J., Castro, A., Durenkamp, M., Stuiver, C. E. E., Westerman, S., Yang, L. and Stulen, I. (2003). Sulphur in plant physiology. *Nawozy i Nawożenie*, *5* (15).
4. Ernst, W.H. (1990). Ecological aspects of sulphur metabolism. *Sulphur Nutrition and Sulphur Assimilation in Higher Plants, SPB Academic Publishing, The Hague*, 131-144.
5. Giordano, M., Norici, A. and Hell, R. (2005). Sulphur and phytoplankton: acquisition, metabolism and impact on the environment. *New Phytologist*, *166*(2): 371-382.
6. Hawkesford, M.J. and De Kok, L.J. (2006). Managing sulphur metabolism in plants. *Plant, Cell & Environment*, *29*(3): 382-395.
7. Huber, D.M. and Haneklaus, S. (2007). Managing nutrition to control plant disease. *Landbauforschung Volkenrode*, *57* (4): 313.
8. Komarnisky L.A., Christopherson R.J. and Basu T.K. (2003) Sulphur: its clinical and toxicologic aspects. *Nutrition*, 19: 54–61.
9. Krouse, H.R. and Tabatabai, M.A. (1986). Stable sulphur isotopes. *Sulphur in agriculture*, *27*: 169-205.
10. Marshner, H. (2005) *Mineral Nutrition of Higher Plants*. Secondedition. Elsevier Academic Press, London, UK.
11. Rego, T.J., Wani, S.P., Sahrawat, K.L. and Pardhasaradhi, G. (2006). Macro-benefits from boron, zinc and sulphur application in Indian SAT: A step for Grey to Green Revolution in agriculture. *Journal of SAT Agricultural Research*, *2*(1): 1-21.
12. Schnug, E. 1990. Sulphur nutrition and quality of vegetables. *Sulphur in Agriculture*, 14: 3-7.
13. Zhao, F.J., Tausz, M. and Kok, L.J.D. (2008). Role of sulphur for plant production in agricultural and natural ecosystems. In *Sulphur metabolism in phototrophic organisms*, Springer, Dordrecht, pp. 417-435.